District Science Leaders: Beliefs and Pedagogical Content Knowledge for Scientific Argumentation

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DISTRICT SCIENCE LEADERS: BELIEFS AND PEDAGOGICAL CONTENT KNOWLEDGE FOR SCIENTIFIC ARGUMENTATION

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ABSTRACT

District Science Leaders: Beliefs and Pedagogical Content Knowledge for Scientific Argumentation

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The Next Generation Science Standards (NGSS) represent a significant shift in the goals of U.S. science education. Instead of a focus solely on content acquisition, the NGSS aim to engage students in the practices of science. Teachers will require substantial support, in large part from science leaders at the district level, to change their instruction to accomplish this vision. However, little is known about how these leaders conceptualize the NGSS. Therefore, this dissertation utilizes a sensemaking theoretical framework to explore the beliefs and pedagogical content knowledge (PCK) of district science leaders about one of the NGSS science practices, scientific argumentation. Greater understandings of these constructs can aid in designing appropriate supports for district leaders and meeting the challenges of implementing the NGSS.

Fifty-three district leaders from states that have adopted the NGSS participated in a survey focused on their beliefs and PCK for argumentation. After the administration of the survey, 10 district leaders who represented a range of states and beliefs were selected for follow-up interviews. These interviews were semi-structured and focused on the same areas of belief as in the survey.

The findings from the surveys and interviews indicate that most district science leaders are supporters of the NGSS and believe that scientific argumentation offers important benefits for students. Many leaders referenced one or more of the NGSS science practices in their descriptions of effective science education and asserted that they believe that the NGSS will require teachers in their districts to make substantial changes in their current instruction. However, some leaders also maintained their beliefs in the effectiveness of traditional instructional methods that are not compatible with the NGSS, and few leaders mentioned critique as an essential component of argumentation. In addition, many leaders demonstrated challenges in their PCK for argumentation, specifically related to evidence and reasoning in scientific arguments and the role of critique in dialogical interactions. Therefore, supporting leaders to develop more accurate conceptions and knowledge of the NGSS and argumentation should be a priority for districts nationwide.

For my husband Jordy,
and my children Abby, Sarah, and Ari
Your love, support, and patience made this possible.

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CHAPTER 1: INTRODUCTION

Today's newspapers are rife with reports about scientific discoveries and technological advances. Politicians, researchers, and members of the general public regularly debate topics such as climate change and genetic engineering. The pervasiveness of such discourse frequently generates debate about whether schools, and specifically science classes, are effectively preparing students to participate and compete in a world of such complexity (PCAST, 2010; NRC, 2012). These concerns are compounded by international test results that demonstrate that American science students perform at or below the levels of students in other developed countries, and that student scores decrease as students get older (National Science Board, 2004; Valverde & Schmidt, 2007). For many researchers, educators, and policymakers, implementing the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) is a critical step toward addressing these issues. Based on a broad research base described in *A Framework for K-12 Science Education (Framework)* (NRC, 2012), the NGSS present a vision for science education that reflects new understandings about how children learn and how scientific knowledge develops. As such, the NGSS have been heralded as one way to prepare America's students to be internationally competitive and capable of becoming active participants in a democratic society (NRC, 2012, NRC, 2015).

Ensuring that American students experience the types of science learning intended by the NGSS, however, will be a demanding task because the NGSS "represents a significant departure" (Bybee, 2014, p. 213) from previous standards and typical science teaching. The most substantial challenge comes from the NGSS focus on instruction that integrates important content with science practices (Bybee, 2011). This emphasis on practices, such as scientific argumentation, is intended to improve students' understandings of how science actually works while supporting them in more deeply learning content (Osborne, 2014). Yet, it stands in contrast to typical science instruction in U.S. classrooms (Bybee, 2014). Therefore, while research about effective science teaching and learning may support such a focus (NRC, 2012), the entire system of science education, including classroom instruction, assessments, and professional development will need to be transformed to reflect these new priorities (NRC, 2015). One important group of stakeholders in the science education system are district science leaders who are charged with crafting policies to ensure teachers have opportunities to learn to teach in ways aligned with the NGSS (NRC, 2015). As such, the understandings and knowledge of district science leaders about the NGSS are an essential factor in how teachers make sense of the NGSS and how the NGSS are translated into their classroom instruction.

The NGSS as an Educational Change

The NGSS are an educational policy aimed at "fundamentally alter[ing] the landscape of American science education" (Achieve, Inc. & U.S. Education Delivery Institute, 2013, p. 4). Similar to other such national and state reforms, they aim to prescribe what teachers should teach and what students should learn (Porter et al., 2011). As such, they are one of the newest standards-based reforms (Thompson, 2001). These types of policies have flourished over the last 30 years (Hamilton et al., 2008), as policymakers and educators have sought to increase the consistency of and raise the expectations for education in the U.S. (Porter et al., 2011). The NGSS were developed after previous efforts to standardize science education in the U.S. saw limited success

(Pruitt, 2014).

The Development of the NGSS

The first two attempts at national standards were the *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (*NSES*) (NRC, 1996). However, neither of these standards was adopted by any state, and instead, states used these documents to craft their own state science standards. The resulting state standards typically did not reflect the research-based goals of the *Benchmarks* or the *NSES* and instead most often emphasized large amounts of factual information and low-level skills (PCAST, 2010). Therefore, in 2007, the National Research Council asserted that despite 15 years of focused, standards-based reform, improvements in U.S. science education were "modest at best" (Duschl, Schweingruber, & Shouse, p. 11) and organizations such as the Carnegie Corporation of New York (2009) called for a new set of national science standards to ensure American students could compete in the 21st century global economy. In 2012, with funding from Carnegie, the National Research Council (NRC) published the *Framework* to direct the development of these standards. Achieve, a non-profit, bipartisan education reform organization then convened representatives from 26 states to use the *Framework* to write the NGSS. The NGSS were released in 2013 (NGSS Lead States).

While previous national standards had limited impact, the NGSS are poised to be far more influential for several important reasons. First, state representatives participated in the NGSS development process and these states will ultimately decide whether to adopt the NGSS in place of current state science standards. In addition, the NGSS are intentionally aligned with the Common Core State Standards (NRC, 2012; Bybee, 2014), which have been adopted by most states. Finally, the NGSS were developed in partnership with several influential science education organizations such as the National Science Teachers Association (NSTA) and the American Association for the Advancement of Science (AAAS) (Pruitt, 2014). As such, the NGSS are positioned to be the science standards states implement to influence science instruction for the next decade (NGSS Lead States, 2013). At the current time, 17 states and the District of Columbia have adopted the NGSS in place of state science standards, and many other states are considering their adoption or adaptation.

Typical Science Instruction and Current State Standards

For states that have or will adopt the NGSS, these new standards establish a vision for science education that differs significantly from both typical science instruction and current state standards (Bybee, 2014). Research on U.S. classrooms demonstrates that science teaching is most often teacher or textbook-directed and focused on content acquisition (Alozie, Moje, & Krajcik, 2010; Driver, Newton & Osborne, 2000; DeBoer, 2000). Such instruction has been criticized for focusing on too many topics in too little depth (Pruitt, 2014; Valverde & Schmidt, 2007; NRC, 2012) and failing to provide students with accurate understandings of the epistemological basis of science (Lehrer & Schauble, 2006; Osborne, 2014). While research on scientists demonstrates the collaborative and social nature of their work (Latour & Woolgar, 1986; Passmore & Svoboda, 2012), classrooms are dominated by discourse patterns and instruction that are teacher-centered (Pimentel & McNeill, 2013; Minner, Levy & Century, 2010; Alozie et al, 2010; Berland & Reiser, 2009). As such, students often inaccurately perceive science to be positivistic, consisting of a set scientific method, or view science solely as a final product rather than a process (Lehrer & Schauble, 2006; NRC, 2012). Osborne (2014) laments that science instruction most often focuses on “persuading students of the validity of the account of nature” (p. 178) rather than the collaborative construction of knowledge by students. Current state standards reinforce this type of instruction by emphasizing large amounts of factual information and low-level skills (PCAST, 2010), and presenting content and skill separately (Pruitt, 2014).

The Goals of the NGSS

One way the NGSS aim to change science education in the U.S. is by presenting a more authentic vision of science that exists at the nexus of three dimensions: disciplinary core ideas (DCIs), crosscutting concepts (CCCs), and science practices. The DCIs in the NGSS are similar to the science concepts in current state standards, although the NGSS include fewer of these concepts and in more depth. Researchers have described the “superficial” nature of science education and curricula that only “skim the surface” of most science ideas (Atkin & Black, 2003, p. 79). This has resulted in students learning “multiple disconnected pieces of information” (NRC, 2012, p. 2-7) instead of developing an in-depth knowledge base. Therefore, the NGSS include fewer topics in more detail. However, similar to previous standards the NGSS divide the DCIs into three categories: life science, physical science, and Earth science. The CCCs, similar to “unifying themes” of other standards documents (e.g., NRC, 1996), therefore provide students with an “organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world” (NRC, 2012, p. 4-1). These CCCs include concepts such as patterns, structure and function, and cause and effect, which are important in all science disciplines.

While the DCIs and CCCs in the NGSS differ in several ways from previous standards, it is the final dimension, science practices, which represent the most significant instructional change demanded by the NGSS (Bybee, 2011) (Figure 1.1). Some practices, such as asking questions and designing investigations appear in several state standards, although they are rarely directly tied to content (Lerner, Goodenough, Lynch, Schwartz, M. & Schwartz, R., 2012; Pruitt, 2014) as they are in the NGSS. In addition, the practices that require more sustained critical thinking and evidence evaluation, such as scientific argumentation, rarely appear in state standards. Therefore, one fundamental goal of the NGSS is for students to engage in a range of authentic science practices both to learn and demonstrate knowledge of important science ideas, and to develop deeper understandings about how scientific knowledge develops (Pruitt, 2014). Research about how scientists work and students learn best supports this focus (NRC, 2012; Sawyer, 2006). An emphasis on these practices, therefore, necessitates a move away from typical teacher-controlled science learning. Instead, instruction that prioritizes the practices of science requires that students "pose, evaluate and pursue worthwhile questions of their own" (Lehrer & Schauble, 2006, p. 384) and be "knowledge producers rather than as consumers of knowledge produced by others" (Jimenez-Aleixandre, 2008, p. 96).

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Figure 1.1. The 8 NGSS Science Practices

This goal of students constructing instead of just memorizing knowledge is an important aspect of the NGSS. However, engaging in the process of building knowledge necessitates that students also engage in critiquing knowledge, because for scientists, "it is this process that results in reliable knowledge" (Osborne, 2014, p. 182). As such, while all of the practices represent essential aspects of the work of scientists, the "engaging in argument from evidence" practice (Figure 1.1) has been singled out as one of the most important (Osborne, 2014).

To demonstrate how these three dimensions are integrated in the NGSS, Figure 1.2 presents a 4th grade standard. In standard "4-LS1-1" the DCI is a life science concept about the relationships between animal and plant structures and functions. The CCC relates to the overall theme in science that systems are defined both by their components and interactions between the components. Finally, the practice of engaging in argument from evidence is intended as a way for students to learn and demonstrate their understanding of the DCI. In this way, the goal is not simply for students to be able to explain content, but also to develop deep conceptual understandings of important science ideas through the practices of scientists (Osborne, 2014).

4-LS1-1 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

Figure 1.2: Sample NGSS Standard

Implementing The NGSS

Implementing the NGSS represents a challenge for the entire system of science education in states that have adopted the NGSS (Southerland, Settlage, & Brickhouse, 2014). The NGSS Adoption and Implementation Workbook (Achieve, Inc. & U.S. Education Delivery Institute, 2013) explains, “[e]ach state adopting and implementing the NGSS will need to equip and motivate hundreds or thousands of district leaders, principals and teachers to change their day-to-day practices” (p. 5).

District science leaders. District science leaders are the individuals who support science teachers in multiple schools in a single school district in their instruction and professional learning. They are essential to the successful implementation of NGSS, and therefore cited in implementation documents, such as those from the NRC (2015) and Achieve (2013), because along with school leaders, district leaders are central figures in the design and delivery of professional learning for teachers (Desimone et al., 2002; Lee et al., 2014; Corcoran, Fuhrman & Belcher, 2001). Substantial professional development will be necessary for teachers to shift their instruction to meet the goals of the NGSS (Banilower et al., 2014; Reiser, 2013; NRC, 2015). While principals tend to focus their efforts on literacy and math (Spillane, 2005), it is district leaders who more often are responsible for professional development in science (Whitworth, Maeng, Wheeler, & Chiu, 2014). Therefore, how district leaders come to understand the goals and instructional implications of the NGSS can greatly influence the ways teachers instruct in their classrooms (Spillane, 2004).

While district science leaders will likely shoulder much of the responsibility to provide teachers learning experiences that enable instructional change, little is known about their understandings of the NGSS. District-led educational change must help teachers understand the fundamental instructional shifts (Fullan, 2007) necessitated by the NGSS and help teachers reconceptualize “what it means for students to learn science” (Reiser, 2013, p. 8). However, there is currently no research base about district science leaders’ beliefs and knowledge about the NGSS. We do not know if they believe there are significant differences between current instruction and the types of instruction demanded by the NGSS, nor do we know if they possess the knowledge of how to teach in ways aligned with the NGSS that will be critical to their leadership of teachers (Stein & Nelson, 2003). Such research seems crucial to designing supports that enable leaders to guide and mentor teachers through their change processes in the most effective ways.

The Problem

In this study I explore the beliefs and pedagogical content knowledge (PCK) of district leaders in states that have adopted the NGSS. I focus on these two constructs because beliefs have been shown to greatly impact educational decisions (Pajares, 1992) and PCK is a key element of effective instructional leadership for educational change (Stein & Nelson, 2003). I focus on the beliefs and PCK of district science leaders related to a specific NGSS science practice, scientific argumentation, because the NGSS science practices represent the most substantial shift in science instruction (Bybee, 2011) and scientific argumentation is one of the most important practices (Osborne, 2014). Scientific argumentation represents that ways that scientists debate and critique emerging knowledge to develop new theories based on evidence (Osborne, 2014). However, such learning, especially as related to critique, is rarely a feature of typical science classroom instruction (Henderson et al., 2015).

My findings will offer insights into the ways that district science leaders are making sense of argumentation and inform the types of educational experiences they may need to effectively lead teachers in accomplishing the monumental changes demanded by the NGSS. Specifically, in this study I focus on the following research questions:

1. What are district science leaders' beliefs about the differences between scientific argumentation and typical science instruction?
    a. What are district science leaders' beliefs about effective science instruction?
    b. What are district science leaders' beliefs about the teaching and learning of scientific argumentation?
2. What are district science leaders' pedagogical content knowledge (PCK) for scientific argumentation?
3. What are district leaders' beliefs about the alignment of argumentation with current science instruction in their districts?

Dissertation Overview

In this Chapter, I provided an overview of the problem and research questions related to leaders' beliefs and knowledge of science instruction, and specifically scientific argumentation. In chapter 2, I present a review of the literature that informs this study of district science leaders’ beliefs and PCK. In Chapter 3, I describe a research design to explore the beliefs and PCK of district science leaders, including methods for data collection utilizing a survey and interviews, and the means of data analysis. In Chapter 4, I present five themes that emerged from the quantitative and qualitative data. Specifically, three themes relate to leaders’ beliefs about effective science instruction and argumentation, one theme characterizes leaders’ PCK for argumentation, and one theme describes leaders’ beliefs about the alignment of instruction in their districts with scientific argumentation. In Chapter 5, I draw on relevant research to draw conclusions about leaders’ beliefs and PCK, and suggest implications for these findings. I close with a discussion of the limitations of this study and possible areas for future research.

CHAPTER 2: LITERATURE REVIEW

This study about district leaders' beliefs and pedagogical content knowledge (PCK) for scientific argumentation brings together four areas of educational research: sensemaking and educational beliefs, PCK, district-level instructional leadership for educational change, and scientific argumentation. In this chapter I will first explain the sensemaking theoretical framework used to guide this study and its connection to research about standards-based reforms and educational beliefs. Then, I will describe research about PCK, focusing on the ways PCK has been investigated in science education. Next, I will describe research about instructional leadership and specifically the ways beliefs and disciplinary knowledge can impact instructional leadership at the district level. Finally, I will explore research about scientific argumentation with attention toward literature about beliefs of and PCK for argumentation.

This study focuses specifically on the beliefs and PCK of district science leaders in states implementing NGSS because while such individuals are often responsible for crafting professional development for teachers, making curricular decisions, and supervising teachers (Whitworth, Maeng, Wheeler, & Chiu, 2014), they are rarely the subjects of educational research (Firestone et al., 2005). The absence of such a focus means that while such individuals impact teachers' instruction in the classroom, we do not understand the beliefs and knowledge that influence their work. Developing such an understanding, therefore, is essential in designing appropriate learning experiences for district science leaders. In this study, district science leaders will be defined as those whose primary responsibility is to design professional development, select curriculum, supervise, and/or in other ways instructionally support science teachers across multiple schools in a single district. Scientific argumentation, which is the science practice on which I focus, is defined as both a structure, in which students utilize evidence and scientific reasoning to support a claim, and a dialogic process in which students debate, critique, and question their peers' arguments (NGSS Lead States, 2013; Jimenez-Aleixandre & Erduran, 2008). This study will investigate how district leaders conceptualize the differences between typical science instruction and argumentation, and explore their PCK for argumentation.

Sensemaking and Beliefs

In this study I utilize a sensemaking theoretical framework to guide the research design and interpretation of the findings. Sensemaking emanates from organizational science research, and posits that when individuals encounter situations or knowledge different from their current state of understanding, they engage in a process to organize, interpret, and "make sense" of this new information (Weick, Sutcliffe, & Obstfeld, 2005). "[P]eople organize to make sense of equivocal inputs and enact this sense back into the world to make that world more orderly" (Weick et al., 2005, p. 410). This organization of unfamiliar information does not occur in a vacuum; instead, it relies on an individual's previous knowledge, beliefs, and experience – "people make sense of things by seeing a world on which they have already imposed what they believe" (Weick, 1995, p. 15).

In the field of educational policy, a sensemaking orientation focuses on how individuals interpret new policies as similar to or different from their current practices (Spillane, Reiser, & Gomez, 2006). As such, when policies are not implemented with fidelity, it is not simply assumed that individuals are resisting change; instead, it is most likely that they fail to see the ways a new policy is substantially different from their current practice (Spillane, 2004). Sensemaking, therefore, often results in the assimilation of new information into existing knowledge structures and leads to superficial implementation of new policies. Individuals attend to the familiar aspects of new policies and those features that are unfamiliar are either disregarded or not authentically implemented (Spillane, 2004). For practices to truly change, individuals require opportunities to restructure their knowledge bases, a difficult process that requires sustained opportunities to grapple with new ideas (Spillane, 2004).

Standards-based reforms and sensemaking

Given the demands to interpret and communicate new policies, a sensemaking framework is often used in research about standards-based reforms (e.g., Spillane, 2004; Coburn, Toure, & Yamashita, 2009; Coburn & Talent, 2006). While no single definition of standards-based reforms exist, such policies are typically concerned with bringing conformity and efficiency to teaching and learning by describing what content students should learn and master at specific grade levels (Thompson, 2001; Hamilton et al., 2008; Porter et al., 2011). NGSS clearly represents one of these efforts as it specifies the learning objectives and performance expectations in science for students across grades k-12 (NGSS Lead States, 2013).

While the goal of such standards-based reforms is to improve student learning, research indicates that simply adopting new standards will not greatly impact teaching and learning. Rather, it is the implementation of standards that is most crucial (Cobb & Jackson, 2011). Despite all 50 states having content standards in multiple content areas (Hamilton et al., 2008), many of these have failed to have much impact on classroom instruction (Carmichael et al., 2010). The reasons for this are many and varied, but sensemaking of new standards is an important factor, because how leaders and teachers implement standards depends in large part on how they interpret them. Research by Coburn and her colleagues (2006; 2009) highlights this role of sensemaking. These studies about policies requiring instructional leaders to use evidence in educational decision-making found that leaders did not simply act in ways that aligned with the new policies. Instead, they interpreted the policies based on factors such as their previous knowledge, experiences with reforms, and the district organizational structure, and engaged in evidence-based decision-making in different ways. Coburn found similar results in her 2005 study about principals implementing new reading standards in their schools. The principals' sensemaking led to varied decisions about professional development, communication with teachers, and instructional priorities. These differences in sensemaking had enormous implications for teachers' understandings of the new reading policies and their eventual instruction of reading in the classroom (Coburn, 2005).

Given the role of sensemaking in standards implementation, I will use this framework to explore how district science leaders understand the official policy (Levinson, Sutton, & Winstead, 2009) of argumentation (as described in NGSS). Implementing NGSS will likely require district science leaders and teachers to change their conceptions about effective science teaching and learning (Krajcik et al., 2014). With the adoption of NGSS in 17 states and Washington DC and district leaders positioned as the developers of teacher professional development for NGSS (Achieve, Inc. & U.S. Education Delivery Institute, 2013; NRC, 2015), we need a greater understanding of district leaders' beliefs and knowledge for two important reasons: (1)

understanding their current beliefs and knowledge will enable the development of appropriate educational opportunities for district leaders so that they can effectively lead teachers in shifting their instruction related to argumentation; and (2) early challenges with NGSS implementation can be identified and more easily remedied.

Beliefs. A necessary entry point into sensemaking is an examination of individuals' beliefs about educational policy (Levinson, Sutton, & Winstead, 2009). Since the 1960s, educational beliefs have been widely studied (Eisenhart et al., 1988), with an almost exclusive focus on teachers' beliefs. This line of research has shown that beliefs can be highly influential on teachers' classroom instruction (Nespor, 1987; Pajares, 1992; Haney et al., 2002; Roehrig & Kruse, 2005; Bryan & Atwater, 2008; Fletcher & Luft, 2011) and curricular enactments (McNeill et al., 2013a; Wallace & Kang, 2004). For example, Prime and Miranda (2006) found that when teachers hold deficit beliefs about their students, they slow down their instruction and simplify the curriculum to align their teaching with their beliefs. Likewise, Cronin-Jones (1991) describes the ways that teachers' beliefs about how students learn, the role of the teacher in the classroom, and content, strongly influence teacher modifications of curriculum for students. This suggests that for individuals charged with leading teachers, beliefs can play an important role in their actions as well. Therefore, in this study I will build on research of teacher beliefs to explore district science leaders' beliefs. I will define beliefs as "one's convictions, philosophy, tenets, or opinions about teaching and learning" (Haney et al., 2003 p. 367). While some researchers assert that beliefs and knowledge are in fact the same construct (Kagan, 1990), I see this definition aligning more with Richardson (2003) who differentiates between knowledge, which requires an evidentiary basis, and beliefs, which do not. Therefore, in this study, knowledge of argumentation will be explored separately from beliefs about argumentation.

Context and beliefs. While beliefs and instructional practices often cohere, Haney et al. (2002) caution that beliefs should not be used as predictors of actions. Beliefs are complex, and individuals can hold contradictory beliefs (Wallace & Kang, 2004; Katsh-Singer, McNeill, & Loper, in press) that make their subsequent actions seem inconsistent with their espoused beliefs. For example, Mansour (2013) describes a teacher who believes that students should interact with each other to learn science, but in practice relies on the textbook to convey knowledge to students. Likewise, Zohar (2008) has found that teachers may profess to teach in new ways but actually continue to teach in traditional ways. One reason such contradictions may exist is that context can influence how beliefs are enacted (Mansour, 2013; Millner et al., 2012; Powers, Zippay, & Butler, 2006; Fang, 1996). Such contexts, which include, but are not limited to, policy mandates, administrator priorities, and school culture, can impact how individuals act on their beliefs (Brown & Melear, 2006; Powers, et al., 2006; Fletcher & Luft, 2011). McLaughlin & Talbert (1993) assert that states engaged in new reforms can be one of these contexts. This suggests that district leaders in different states may hold varied beliefs about the NGSS and therefore may make different decisions regarding curriculum, professional development, and other aspects of teacher learning about argumentation.

This study will hopefully provide a better understanding of the beliefs of district science leaders, which can be useful in designing their professional development experiences (Reiser, 2013) and understand the implementation challenges of NGSS. Research has shown that professional development must address the beliefs that individuals bring with them to be effective (Fetters et al., 2002). As Spillane and Callahan (2000) assert, “understanding where one’s learners are at is an essential first step in trying to instruct them on where one wants them to go” (p. 420). Other research supports this notion: individuals must be convinced of the ineffectiveness of their current beliefs to change them (Posner et al., 1982; Pajares, 1992) and the effectiveness of new ideas to adopt them (Mansour, 2013). While there are multiple factors that impact beliefs (Brown & Melear, 2006), and actions do not necessarily align with beliefs (Mansour, 2013), understanding district leaders’ beliefs is an important step in the design of their professional development. Likewise, beliefs can provide a window into the implementation of NGSS because “how individuals and groups respond to new accountability pressures is likely to be shaped by their preexisting beliefs” (Coburn & Talent, 2006, p. 491).

Pedagogical Content Knowledge (PCK)

While research indicates that beliefs about argumentation will likely influence the work of district science leaders, they will also likely need a specialized type of knowledge about argumentation called pedagogical content knowledge (PCK). Shulman developed this term in his speech to the American Educational Research Association (AERA) and subsequent article (1987) in the *Harvard Educational Review.* In describing a seven-part knowledge base for teaching, Shulman defined PCK as a blending of subject-matter knowledge and pedagogical knowledge “into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students” (Shulman, 1987, p. 15). Shulman (1987) asserted that teachers who possess PCK design their instruction in a manner that simultaneously attends to the “difficulty and character of the subject matter, the capacities of the students … [and] educational purposes" (Shulman, 1987, p. 3). Teachers with PCK have a deep understanding of content and can transform their knowledge (Abell, 2008) to make this content comprehensible to their students. While PCK is most often discussed related to teachers, research has also found this type of knowledge important to instructional leaders (Stein & Nelson, 2003).

PCK and Instructional Leaders

Research indicates that PCK can be an important component of the knowledge base of not only teachers, but also instructional leaders, because PCK is necessary for instructional leaders to design effective learning opportunities for teachers, make curricular decisions, and support adult learning about content in other ways (Stein & Nelson, 2003). Therefore, for district science leaders charged with designing professional development for teachers related to science practices such as argumentation, possessing PCK specifically for argumentation is essential. While studies exist that consider other components of leaders' knowledge, none to date specifically measures or assesses PCK for science. Consequently, in this study I will examine district science leaders' PCK for argumentation. A greater understanding of their PCK for argumentation could provide both direction for their future professional learning (Schneider & Plassman, 2011) and insight into whether the teachers with whom they work are likely to develop PCK for argumentation.

Defining PCK for Science Teaching

Shulman's (1987) original definition of PCK consisted of two components: 1) knowledge of student's conceptions of specific content; and 2) knowledge of strategies to address these conceptions. While Shulman intended PCK to be discipline-specific, his initial definition did not specify PCK for any discipline. Therefore, researchers in various academic fields began to explore and define PCK for their respective content. Soon after Shulman defined PCK to include students' understanding of a topic and instructional strategies, various science education researchers adapted this definition for science teaching. Smith and Neale (1989) proposed adding a third component to PCK related to science teaching. They asserted that PCK for science teaching must include an aspect that attends to teacher beliefs about "what science is, how scientific knowledge becomes established, and how it ought to be taught and learned" (Smith & Neale, 1989, p.4). They maintained that teachers who possess a "conceptual change" orientation toward science teaching instruct in ways that target student misconceptions and promote student understanding about "appropriate ways to establish knowledge claims in science" (Smith & Neale, 1989, p. 4).

In 1993, Geddis modified Shulman's original definition of PCK, suggesting that another component should be science teachers' knowledge of curriculum. In describing a group of preservice secondary science teachers debating how to teach electrical current flow in a simple circuit, Geddis demonstrated that even adults with a physics background may not comprehend complex concepts, in this case the difference between electrical flow and electrical energy. Geddis argued, however, that identifying misconceptions and teaching strategies that help students is insufficient; teachers must be able to plan and carry out instruction that makes the content understandable to young students.

In 1999, Magnusson, Borko, & Krajcik greatly expanded PCK to include five components:

- *Orientations toward science teaching:* general views about science teaching, knowledge and beliefs that influence how science is taught;
- *Knowledge of science curriculum:* knowledge of mandated goals and objectives (i.e., state frameworks), knowledge of specific curricula and associated materials;
- *Knowledge of students' understanding of science:* knowledge that teachers need about students to effectively teach;
- *Knowledge of assessment in science*: knowledge of what should be assessed and the most effective methods of assessment;
- *Knowledge of instructional strategies:* knowledge of subject-specific instructional techniques, knowledge of topic-specific instructional techniques.

Similar to Smith and Neale (1989), Magnusson et al. (1999) include orientations toward science teaching in their definition. However, in the Magnusson et al. conceptualization, orientation toward science teaching is not just one of five components, it is the most important component and the one through which all other components are filtered; orientations to teaching science affect the four other components. Unlike Smith and Neale (1989) who favor a conceptual change orientation toward science teaching, Magnusson et al. (1999) promotes a guided inquiry orientation in which teachers created a "community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science" (p.100). Magnusson et al. (1999) argue that a guided inquiry orientation is more likely to result in instruction that is learning community-centered and supports students in conducting experiments, analyzing data, and assessing the validity of data and conclusions.

Despite these and other models of PCK for science teaching (e.g., Park & Oliver, 2008), most definitions of PCK in science maintain Shulman's original two components (Park et al., 2011; van Driel et al., 1998): 1) knowledge of students' conceptions of specific content; and 2) knowledge of strategies to address these conceptions. These two aspects have been empirically shown to be synergistic and "critical in shaping the structure of a teacher's PCK" (Park & Chen, 2012, p. 937). Therefore, these two components related to PCK for argumentation will be measured for district leaders in this study. This is not to say that other aspects of PCK are not important; however, these two components have been described as key parts of the foundation of teachers' PCK for argumentation in the classroom (Osborne, 2014; McNeill et al., 2016). This suggests that they are also essential for district science leaders who will craft professional development and make curricular decisions related to scientific argumentation.

Measuring PCK

While research has found relationships between PCK and classroom instruction (Avraamidou and Zembal-Saul, 2005; Avraamidou and Zembal-Saul, 2010; Park et al., 2011), measuring PCK has been very difficult (Baxter & Lederman, 1999; Carlson et al., 2014). One reason is that PCK is complex and often considered a tacit or hidden kind of knowledge (Kind, 2009). For example, observing a teacher in a classroom can only demonstrate a subset of the teacher's instructional moves and also may not reveal the teacher's reasoning (Baxter & Lederman, 1999). Therefore, most studies of PCK are small-scale and utilize multiple data sources such as observations combined with interviews (Baxter & Lederman, 1999). Hill and colleagues (2004; 2008) have attempted to develop an instrument that measures PCK in the hopes that larger scale studies can be conducted and teacher learning can be more readily evaluated. Hill and colleagues (2004;

2008) utilized a three-step process to develop an instrument to measure the PCK of math teachers. These same steps, conceptualizing the domain, developing assessment items, and field-testing the items, were later used by McNeill et al. (2016) to develop an assessment of teachers' PCK for argumentation that measures teachers' knowledge of student conceptions of argumentation and instructional strategies to address these conceptions. This is the instrument that will be used in this study, because it targets the constructs of interest and is easily distributable to district leaders across the country. Consequently, the instrument will provide insights into whether district leaders have developed or are in the process of developing PCK for argumentation, a necessary component of their knowledge base.

District Leaders and Instructional Leadership

Since the 1980s, the concept of "instructional leadership" has been widely explored (Hallinger, 2003). Multiple models of this construct exist (Hallinger, 2003) to explain the characteristics, roles, and actions of those charged with directing improvements in teaching and learning (Elmore, 2000). However, most research exploring instructional leadership focuses on the school principal, not those at the district level (Spillane, 2004). There are several explanations for this omission, including that district dynamics are too complex to adequately capture in research (Leithwood et al., 2004), that districts are the sites of problems rather than solutions in educational reform (Tyack, 2002), and that the accountability demanded by the standards movement requires a focus on school-based factors (Elmore, 2000). A small body of research, however, has found that districts and their leaders can play key roles in educational reform. Researchers suggest that the breadth of financial and intellectual resources districts possess, and their abilities to influence a wider array of schools, actually make districts the ideal entities to guide educational change (McLaughlin & Talbert, 2002; Firestone, 2009).

A key example of a way that instructional leadership at the district level can support educational change comes from Community School District #2 in New York City. Faced with a need to overhaul the teaching of literacy, the superintendent and his central office staff created a district-wide collaborative culture focused on continual improvement to change instructional practices and student learning in reading. This educational change was primarily accomplished through sustained professional development that enabled teachers to meaningfully change their beliefs and instruction. Elmore and Burney (1997) state that the eventual improvements in student learning in District #2 were a direct result of the district leaders' abilities to craft "a specific set of principles, activities, and structures" geared toward instructional improvement and "to inspire a lot of problem-solving activity in the district around these ideas" (p. 30). Elmore and Burney (1997) argue that research about this district demonstrates not only how district leadership can guide improvements in teaching and learning, but also that districts may actually be best suited to guide such educational change.

Spillane's (2004) work in Michigan offers an insight into why district leaders can have such a profound influence, especially when educational change is demanded by outside influences such as new standards. Spillane (2004) asserts that district leaders act as policymakers, interpreting national and state standards for teachers by designing curriculum frameworks and professional development. Spillane's research in Michigan found that despite new standards that pushed for significant changes in what counted as mathematics and science knowledge, tremendous variation existed in how districts supported such changes and how district leaders understood the differences between current instructional practice and the new standards. District leaders most often assimilated the new standards into their existing knowledge, developing "surface level rather than deeper level understandings of the reform ideas" (p. 88). These leaders missed the critical differences between the reforms and current practices and as a result, they designed policies that did not reflect the fundamental changes in math and science instruction called for by the standards. This line of research should serve as a caution for the implementation of NGSS. As I will describe in the "scientific argumentation" section in this chapter, argumentation necessitates a significant shift in classroom instruction that is unlikely to align with the ways that science teachers currently teach. For district leaders to design the types of professional development that will truly influence teachers' instruction, such leaders will need to possess accurate conceptualizations of argumentation and realize how it is similar and different from what currently occurs in science education.

District Leaders' Beliefs

I will explore the beliefs that district science leaders possess about argumentation because research about educational beliefs, and specifically research by Elmore and Burney (1997) and Spillane (2004), demonstrate that district leaders' beliefs can have a tremendous impact on their actions. Interviews with the superintendent in New York's District #2, for example, revealed the emphasis he placed on leveraging professional development to focus on engaging in learning opportunities designed to improve instruction over time. He stated in an interview in 1992, "We try to model with our words and behavior a consuming interest in teaching and learning, almost to the exclusion of everything else" (Elmore & Burney, 1997, p. 7). Other studies have documented the ways that district leaders' beliefs can influence their actions. Two such studies reveal the ways that conflicting beliefs can derail reforms. Cobb, McClain, de Silva Lamberg, and Dean (2003) describe district leaders whose beliefs about organizing math professional development for teachers conflicted with their beliefs about using test scores as evidence of student learning. Leadership consequently shifted away from designing teacher learning and toward monitoring teachers' coverage of material. Similarly, Sandholtz and Scribner (2006) describe a leader who believed in fostering collegiality between teachers in his district. However, this belief conflicted with his beliefs about maintaining administrative control, teacher expertise, and emphasis on test scores, resulting in competition between schools and teachers.

Another line of research into district leaders' beliefs focuses on the impact of beliefs on professional development opportunities for teachers. For example, Stein and Coburn (2008) found that in two districts implementing new math curricula, district leaders' beliefs about how teachers learn influenced the types of professional learning they offered teachers. In one district, leaders prioritized enabling teachers and coaches to "negotiate the meaning" (Stein & Coburn, 2008, p. 16) of the new math curriculum through different types of learning opportunities between individuals at various levels in the district. In contrast, leaders of the other district saw math learning for teachers as unidirectional and described teacher and coach professional development following a "turn-key" model, where learning was intended to cascade down the leadership structure to teachers. As a result, the first district's teachers and leaders engaged in sustained learning “focused on in-depth discussions of student learning and the nature of mathematics” whereas the second district “focused on superficial discussion and sharing activities” (Stein & Coburn, 2008, p. 23). Therefore, despite initially engaging in similar reform efforts, district leaders’ beliefs about instruction and structuring reform had consequences for how teachers and others in the district experienced the reform.

These studies also demonstrate the importance of leaders’ beliefs about educational change. The superintendent in New York City District #2, for example, believed that teacher change necessitated sustained time, support, and effort, and crafted professional development that reflected these beliefs (Elmore and Burney, 1997). Similarly, the Stein and Coburn (2008) study demonstrates the ways that enacting similar reforms with different theories of change impacts the progression and outcomes of such policies. Therefore, while my study focuses on district leaders’ beliefs about argumentation, I recognize that these beliefs will interact with their conceptions of educational change to impact their subsequent actions (Mangin & Dunsmore, 2015). As such, while the survey focuses on argumentation beliefs, the interview protocol included a question about leaders’ plans for professional development.

District Leaders and Content Knowledge

In addition to beliefs, research suggests that academic content knowledge can influence leaders’ actions. Research by Spillane (2005) at the school level indicates that instructional leaders can engage in different types of leadership activities based on their content knowledge. Leaders in this study were more likely to take an active role in leading teacher development related to literacy because they viewed themselves and the teachers in the school as literacy experts. Conversely, they saw math teaching expertise as residing in the curriculum and outside experts. This influenced leaders' decisions to be less active in leadership activities related to math.

While content knowledge is clearly important, several studies have demonstrated the dual role of content and pedagogical knowledge in the decisions leaders make about teacher learning. For example, Stein and D'Amico (2002) and Stein and Nelson (2002) investigated leaders that utilized their content knowledge to design learning opportunities to develop teachers' conceptual understandings, rather than procedural knowledge, of how to teach content. The superintendent in Stein and D'Amico's (2002) study, who led a district-wide effort to implement a new literacy program, discussed his belief that just like learning to read, learning to teach literacy in new ways takes time and is an intellectually challenging task. Stein and Nelson (2002), later analyzed these same beliefs when the focus shifted to mathematics. The district leaders quickly recognized that learning to teach math is different than learning to teach literacy, and designed learning opportunities that were effective for teacher change relative to math instruction. This research suggests the importance of leaders blending their content and pedagogical knowledge, or possessing PCK, to make leadership decisions. Stein and Nelson (2003) propose that instructional leaders who posses PCK are more likely to engage in leadership activities that effectively impact the abilities of teachers to instruct in in new ways. However, this construct has never been explored for district leaders in science.

District leadership for science. While there is little research of district instructional leadership (Firestone et al., 2005), there is even less specifically examining district leaders in science (Whitworth et al., 2014). The studies that do exist reveal that these individuals are frequently responsible for designing and conducting professional development, selecting curricula, aligning curriculum with standards, and communicating policies to teachers (Whitworth et al., 2014). These science leaders have been found to "play a critical role in how the district views the teaching of science" (Edmonson, Reid, & Sterling, p. 35, 2012) because their choices dictate the types of instruction teachers learn about and whether or not teachers feel supported in their science instruction. This line of research coupled with Spillane's (2004) assertion that district leaders are policymakers suggests that what teachers learn about NGSS and the types of instruction they eventually enact in their classrooms may be directly tied to how district leaders understand NGSS. To best meet the needs of these leaders, it is crucial to explore what they currently believe and know.

Scientific Argumentation

While district leaders will be charged with supporting teachers to teach in ways that reflect the entirety of the NGSS, this study focuses on the beliefs and PCK of district leaders about only one aspect of the NGSS: the science practice of scientific argumentation. This does not mean that other NGSS practices or other aspects of the NGSS are not important. However, by focusing on only one practice, a more in-depth exploration of beliefs and knowledge is possible. In addition, research has shown that beliefs and knowledge about argumentation are also likely related to beliefs and knowledge about other science practices (Zohar, 2008), and that argumentation is one of the most critical yet challenging practices for students and teachers (Osborne, 2014).

NGSS and Science Practices

Scientific argumentation has been the focus of much recent research (e.g., Simon, Erduran & Osborne, 2006; Berland & Reiser, 2009; McNeill, 2009) and is included as one of the eight key science practices for k-12 students in the NGSS (NGSS Lead States, 2013). The goal of this newfound focus on science practices is not to create future scientists, but to support students in building and applying their knowledge (Krajcik et al., 2014) to develop more realistic perspectives about how scientific knowledge develops (Osborne, 2014; Bybee, 2011) and deeper understandings of important content (Pruitt, 2014). Research on how children learn supports this emphasis on practices: students' learning is enhanced when "they engage in activities that are similar to the everyday activities of professionals who work in a discipline" (Sawyer, 2006, p. 4).

While the emphasis previous to the NGSS was on "inquiry" science, this term became ubiquitous (Anderson, 2002) and instruction most often focused on students learning science as an established body of knowledge instead of one that they could participate in creating (Osborne, 2014; Duschl, 2008). While students did enact some of the activities of scientists, such an conducting investigations, most often inquiry science failed to support students in understanding how scientists construct knowledge (Pruitt, 2014). Instruction that prioritizes science practices therefore requires a shift toward students being able to develop and apply their knowledge in new and unique situations (Krajcik et al., 2014). A focus on science practices necessitates that students construct knowledge through engagement in developmentally appropriate activities, discourse, and thinking similar to scientists (NRC, 2012).

Scientific argumentation. For scientists, argumentation represents the ways that they debate and critique their findings (Latour & Woolgar, 1986) to advance scientific knowledge (Osborne, 2014). While there remains a lack of consensus in the research community about what constitutes argumentation (Sandoval & Millwood, 2008; Sampson

& Clark, 2008), I will utilize a two-fold perspective on argumentation in this study that aligns with the definition of argumentation in the NGSS. Appendix F of the NGSS (NGSS Lead States, 2013) describes argumentation as “based on evidence and reasoning” and “the process by which evidence-based conclusions and solutions are reached…Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods” (p. 29). Therefore, argumentation includes both a dialogic process and a structural aspect (Jimenez-Aleixandre & Erduran, 2008). The dialogic process involves students in the types of debate, critique, and questioning that scientists engage in as they interpret and evaluate each other’s evidence and findings (Osborne, 2010). The argument structure includes a scientific claim supported by evidence and reasoning (McNeill & Krajcik, 2012). Evidence is defined as scientific data that support a claim and reasoning is the causal link between evidence and the claim, and often includes the use of a science concept. Students utilize this structure to construct persuasive arguments, which are then debated and critiqued by peers through dialogical interactions. As such, these two elements, the structural and dialogic, function synergistically to enable students to persuade and critique each other and collectively develop deeper conceptual and epistemological understandings of science (Berland & Reiser, 2009).

Benefits of argumentation. One reason argumentation is included in the NGSS is that research has shown a multitude of benefits for students. Argumentation has been linked to improving students’ communication skills, reasoning abilities, epistemic knowledge, critical thinking skills (Jimenez –Aleixandre & Erduran, 2008) and content knowledge (Venville & Dawson, 2012; Zohar & Nemet, 2002). Venville and Dawson (2010) theorize that students’ understanding of content can be impacted because they engage in interesting debates that necessitate that they make connections between various concepts. Since argumentation stands in contrast to the commonly held idea that science is a single set of facts or a single method of inquiry, it can support students in developing accurate concepts of the epistemology of science (Kelly, 2008) and seeing science as a collaborative social enterprise (Sandoval, 2005). In addition, argumentation can help improve students' understandings of the essential role of evidence, data to support a claim, in science (NRC, 2012). Argumentation also engages students in disciplinary literacy practices (Pearson, Moje, & Greenleaf, 2010) and helps develop their abilities to understand and debate important policy issues (NRC, 2012; Tiberghien, 2008). As such, engaging students in practices such as argumentation can significantly change how science is understood and learned in the classroom (Osborne, 2014).

For students to experience the multitude of benefits that argumentation offers, they must have authentic opportunities in the classroom to debate, critique, and revise their ideas (Driver, Newton, & Osborne, 2000) through peer-to-peer argumentation. The types of interactions required by argumentation, however, are very different than the traditional initiate–response-evaluate (IRE) talk in science classrooms (Alozie, Moje & Krajcik, 2010), and are highly dependent on teachers creating a culture in which students can talk to each other, rather than through the teacher (Zembal-Saul, 2009). Developing such a culture requires that teachers (Ford, 2008; Berland & Reiser, 2009; Martin & Hand, 2008) and students (Jimenez-Aleixandre, 2008) significantly shift their roles in the classroom. Research indicates that science instruction typically emphasizes the transmission of teacher knowledge (Berland & Reiser, 2009; Newton, Driver, & Osborne, 1999) and student talk is largely teacher directed (Pimentel & McNeill, 2013; Alozie et al., 2010). Instead, argumentation necessitates a learning environment in which students are confident expressing and defending their ideas, working collaboratively (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000), and persuading their peers (Berland & Reiser, 2009). This poses a difficult task for teachers (McNeill & Knight, 2013) and can require significant time and support to develop instructional strategies for its implementation (Martin & Hand, 2008; Newton et al., 1999; Bartholomew et al., 2004). Furthermore, argumentation necessitates that students utilize scientific data to support and refute claims, an additional shift in classrooms where the role of evidence in science can be misunderstood (McNeill, 2011). Consequently, I will explore whether district leaders conceptualize argumentation as substantially different than typical science instruction.

Argumentation and beliefs. A small body of research has explored argumentation beliefs, although only as related to teachers. These studies establish that teachers can hold a range of beliefs (Katsh-Singer et al., in press) that impact their instructional decisions (Sampson & Blanchard, 2012). Research demonstrates that teachers can believe argumentation is valuable for their students because it promotes critical thinking (Sampson & Blanchard, 2012; McNeill et al., 2013b), supports students in learning important content (Sadler, 2006), and provides opportunities for student talk in the classroom (Katsh-Singer et al., in press). However, teachers can also believe that argumentation will confuse students (Simon, Erduran, & Osborne, 2006; Osborne, Erduran & Simon, 2004) and that argumentation is too hard for some types of students such as low-achievers and those of low socioeconomic status (SES) (Zohar & Nemet, 2002; Zohar, Degani, & Vaankin, 2001; Sampson & Blanchard, 2012; Katsh-Singer et al., in press). Katsh-Singer et al. (in press) found that despite teachers believing argumentation is valuable for all students, teachers of low SES students were more likely to view their students' experiences outside of school as impediments to their successful participation in argumentation. This study also demonstrated that teachers of low SES students held different beliefs about argumentation discourse than teachers of higher SES students. The teachers of low SES students described argumentation akin to increased student talk, whereas the teachers of higher SES students were more likely to see argumentation discourse as an opportunity for students to debate and construct knowledge. These beliefs about argumentation discourse reflect other research that has found that engaging students in such experiences is challenging and an area where teachers often need additional support (Berland & Reiser, 2009).

In this study, I will build on this line of research and utilize a sensemaking framework to explore four potential categories of district leaders' beliefs about argumentation: (1) beliefs about typical science instruction; (2) beliefs about argumentation instruction; (3) beliefs about the benefits of argumentation instruction for students; and (4) beliefs about the ways argumentation aligns with current district-wide instruction. This last category is essential to explore because to effectively support teachers in implementing NGSS, district leaders will need to conceptualize science education in ways that align with the goals of NGSS and which are likely substantially different than the types of instruction currently occurring in classrooms in their districts (Krajcik et al., 2014).

PCK for argumentation. In addition to beliefs about argumentation, this study focuses on district leaders' PCK for argumentation. However, despite a considerable amount of research on PCK in science education, research on PCK for science practices such as argumentation is limited. While “the value of PCK lies essentially in its relation with specific topics” (van Driel, 1998, p. 691), most studies of PCK in science focus on teachers developing PCK for specific science content, such as acids and bases (e.g., Loughrin et al., 2001), not science practices. However, PCK for disciplinary practices is essential if teachers are to design and implement effective instruction that includes science practices (Davis & Krajcik, 2005). This type of PCK is knowledge about the role of practices in science, how to effectively engage students in these practices in the classroom, and how to address common student misconceptions that may hinder learning (Osborne, 2014; Davis & Krajcik, 2005). Osborne (2014) asserts that PCK for science practices is essential for meeting the goals of the NGSS.

Similar to the literature about argumentation beliefs, PCK research focuses exclusively on teachers. In this study, I will attempt to build an understanding of district leaders’ PCK focused on one type of PCK for disciplinary practices: PCK for argumentation. I define PCK for argumentation as including two essential components: leaders’ knowledge of student conceptions and leaders’ knowledge of appropriate strategies to address these conceptions (Shulman, 1987) as related to the two-fold meaning previously described that aligns with argumentation in NGSS: argumentation as a dialogic process and argument as a structure that prioritizes evidence-based accounts (Jimenez-Aleixandre & Erduran, 2008). Therefore, district science leaders’ PCK for argumentation will be assessed related to their knowledge of: (1) student conceptions of and appropriate instruction related to the structure of argumentation, specifically the use of high-quality evidence and reasoning to support claims; and (2) student conceptions of and appropriate instruction to address the dialogical aspects of argumentation, specifically the importance of students building off of and critiquing each other's ideas and multiple claims (McNeill et al., 2016).

While little research currently exists about PCK for argumentation, the studies that do examine this construct demonstrate that elements of both these PCK for argumentation conceptions can be challenging for teachers. McNeill & Knight (2013) found that teachers who participated in a series of argumentation workshops developed PCK for argumentation related to the structural elements of student writing. However, teachers continued to struggle with understanding and supporting students with the structural and dialogic aspects of oral argumentation. Given these findings related to teachers and the limited research base on PCK for argumentation, both the structural and dialogic conceptions described above will be examined for district science leaders.

Summary

Educational research about sensemaking and beliefs, PCK, district instructional leadership, and scientific argumentation suggests that examining the beliefs and PCK of district science leaders related to argumentation can be an important step toward the effective implementation of the NGSS. Developing a better understanding of district science leaders' beliefs and PCK is necessary to design learning opportunities for them and can also provide a perspective on some of the possible challenges in bringing the NGSS into science classrooms. This is essential to ensuring that throughout their school experiences, students experience high quality, research-based science education.

CHAPTER 3: RESEARCH DESIGN

This study used a triangulation mixed methods design (Creswell, 2003) to explore the argumentation beliefs and PCK of district science leaders. Specifically, I employed a convergence model in which I collected qualitative and quantitative data about this topic, analyzed the two types of data separately, and then compared the results to develop themes that characterized district leaders' argumentation beliefs and PCK (Creswell, 2003). This model allowed me to leverage the advantages of both quantitative and qualitative methods (Creswell, 2003; Johnson & Onwuegbuzie, 2004), as the mostly quantitative surveys were easily distributable to a large number of district leaders across the country, and qualitative interviews enabled a more in-depth examination of district leaders' beliefs. These methods were utilized to answer the following research questions:

1. What are district science leaders' beliefs about the differences between scientific argumentation and typical science instruction?
    a. What are district science leaders' beliefs about effective science instruction?
    b. What are district science leaders' beliefs about the teaching and learning of scientific argumentation?
2. What are district science leaders' pedagogical content knowledge (PCK) for scientific argumentation?
3. What are district leaders' beliefs about the alignment of argumentation with the current science instruction in their districts?

To address these questions, I first administered a survey to district science leaders that focused on their beliefs and PCK for argumentation. I then interviewed a subset of these participants to gain further insight into their beliefs. The survey consisted of three parts. The first part asked for background information from participants. The second part contained Likert-scale and open-ended items focused on beliefs (research questions 1 and 3). The third part was an assessment of PCK for argumentation that included multiple-choice and open-ended items (research question 2). The belief portion targeted district science leaders' beliefs about typical science instruction, argumentation instruction, the value of scientific argumentation for students, and whether or not they believe that the types of instruction currently occurring in their district align with argumentation. The second part of the survey measured district science leaders' PCK for scientific argumentation using vignettes of classroom instruction and dialogue. The survey is contained in Appendix A. Follow-up interviews with a selection of survey participants focused on the same areas of belief as the survey. The interview protocol is contained in Appendix B. In this chapter, I will describe the methods in detail including the participants, the data sources, and how I analyzed the data.

Survey Development

The survey instrument consisted of three main parts: (1) participant background information; (2) Likert scale and open-ended items targeting beliefs; and (3) multiple-choice and open-ended items assessing PCK for argumentation.

Background information

This first section of the survey was designed to collect information about participants (Appendix A2). Items included personal information such as race and gender, information about experience as a district administrator, information about their current district position such as their job responsibilities, and their familiarity with argumentation, such as whether they have ever attended professional development about argumentation. In addition, since context has been shown to influence beliefs (Jones & Carter, 2007), several questions focused on information about the district and state in which they work, such as whether they work in an urban, suburban, or rural district.

Beliefs

The second part of the survey (Appendix A3) contained Likert scale and open-ended items based on four categories of beliefs: (1) typical science instruction; (2) argumentation instruction; (3) the value of argumentation instruction for students; and (4) the alignment of argumentation instruction with science instruction in the district (Table 3.1). These types of beliefs reflect the sense-making theoretical framework (Spillane, 2004) that I am utilizing and therefore are focused on exploring whether district leaders conceptualize argumentation as substantially different than typical science instruction. Likert scale and open-ended items were used for each belief category. For the Likert scale items, a four-point scale was utilized (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree) and teachers were asked the extent to which they agree or disagree with statements (DeVellis, 2003). Ten statements were included for each of these first three categories of belief and one statement for the final belief category. These statements were positively worded because it has been suggested that “negatively worked items either do not exhibit as high a reliability as positively worded items or can be confusing to respondents” (Netemeyer, Bearden, & Sharma, 2003, p. 99). Before administration, an expert in the field of argumentation reviewed the items and I conducted cognitive interviews with two district leaders to ensure the Likert scale items targeted the intended constructs. Based on these interviews I made changes to the items to increase their content validity (DeVellis, 2003). For example, one of the initial Likert scale items was: "It is important for students to talk directly to each other during scientific argumentation discussions." However, neither district leader that I interviewed interpreted this item as referring student-to-student discourse, a key component of argumentation in the classroom (Driver et al., 2000; Berland & Reiser, 2009). Instead, one district leader believed this item referred to the arrangement of desks in the classroom so that students are in close proximity to each other, and the other district leader explained that it is important for students to have opportunities to voice their ideas in school. Therefore, to increase the content validity of the item so it would target leaders' beliefs about the importance of student-to-student interactions during argumentation, I changed this item to: "Student-to-student interactions are an important part of scientific argumentation in the classroom."

Table 3.1
4 Belief Categories

Belief Category	Definition
Typical Science Instruction	Leaders' beliefs about the effectiveness of the types of instruction that are typical in science classrooms, such as teachers presenting information to students and students conducting experiments after they learn specific content.
Argumentation Instruction	Leaders' beliefs about the effectiveness of the types of instruction that align with a focus on argumentation, such as students evaluating evidence and engaging in persuasion of their peers.
Value of Argumentation for Students	Leaders' beliefs about the value of scientific argumentation instruction for students, related to science (i.e. learning content) and other educational benefits (i.e. developing critical thinking, reading, and writing skills).
Alignment of Argumentation with Current Science Instruction	Leaders' beliefs about whether or not argumentation aligns with the ways teachers currently instruct in their district, and the ways that argumentation is similar to and different from this instruction.

I will now describe the design of the Likert scale and open-ended items for each belief category (Table 3.1). Examples of these items are included in Table 3.2.

Table 3.2
Sample Belief Survey Items

Belief Category	**Sample Likert Scale Items**	**Sample Open-Ended Items**
Beliefs about typical science instruction	Hands-on activities are the best way for students to learn science.[1]	What do you believe good science instruction looks like?
Beliefs about argumentation instruction	During class discussions students should be persuading each other of their ideas.[1]	
Beliefs about the value of argumentation	Engaging in argumentation is an effective way for students to learn important science concepts.[1]	What do you believe are the benefits to students, if any, of engaging in scientific argumentation?
Beliefs about alignment between current district instruction and argumentation	Overall, the science instruction in my district is closely aligned with the goals of scientific argumentation.[1]	In what ways does the instruction of teachers in your district align with scientific argumentation?

[1] 1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree

Beliefs about typical science instruction. These items were designed to explore whether district science leaders' beliefs about science teaching and learning align with typical science instruction. The Likert scale statements were written to reflect common problems with typical science instruction as described in NGSS (NGSS Lead States, 2013), *The Framework for k-12 Science Education* (NRC, 2012), and related research (e.g Zembal-Saul, 2009). For example, "Hands-on activities are the best way for students to learn science" (Table 3.2). This particular statement reflects findings from Zembal-Saul (2009), who asserts that a primary focus on hands-on activities is common in science classrooms, but contrasts with instruction focused on argumentation. Other items targeted common elements of science instruction such as teachers presenting information to students (Berland & Reiser, 2009; Newton, Driver, & Osborne, 1999) and student talk being directed by the teacher (Alozie et al., 2010). One open-ended item also targeted this construct and asked district leaders to explain what they believe good science instruction looks like. This open-ended item cut across this category and the "beliefs about argumentation instruction" category because it was intended to explore whether leaders' beliefs align with typical instruction or with argumentation-focused instruction.

Beliefs about argumentation instruction. These items were designed to explore whether district science leaders' beliefs about science teaching and learning align with argumentation instruction. The Likert scale statements were written to reflect aspects of effective argumentation instruction as described in the NGSS (NGSS Lead States, 2013), *The Framework for k-12 Science Education* (NRC, 2012), and related research (e.g., Driver et al., 2000). For example, "During class discussions students should be persuading each other of their ideas" (Table 3.2). This statement focuses on persuasion, which is a key aspect of argumentation in the classroom (Berland & Reiser, 2009). Other key constructs targeted in the items included engagement of students in critique (Ford, 2008) and student-to-student discourse (Berland & Reiser, 2009). As previously mentioned, one open-ended item targeted this construct and the "beliefs about typical science instruction" construct.

Value of argumentation for students. This category of belief reflects findings by McNeill et al. (2013b), Katsh-Singer et al. (in press), and others (e.g., Sadler, 2006) that teachers can believe argumentation offers important benefits to students, even if they lack a deep understanding of what counts as argumentation. Therefore, these items were designed to assess the ways that district science leaders believe argumentation benefits students. Likert scale statements described benefits related to argumentation as established by research such as content knowledge, critical thinking skills, and literacy benefits (e.g., Jimenez-Aleixandre & Erduran, 2008). For example, "Engaging in argumentation is an effective way for students to learn important science concepts" (Table 3.2). Teachers who believe argumentation benefits students report being more willing to include argumentation in their classrooms (Sampson & Blanchard, 2012). Therefore, for district science leaders, these items can indicate their understanding of the importance of argumentation, whether they are likely to design effective argumentation professional development in their districts, and their needs for professional development related to argumentation. Two open-ended items for this category of belief asked district leaders to explain what they believe are the benefits and drawbacks, if any, of argumentation instruction for students.

Alignment of argumentation with typical science instruction. This final belief category enabled an examination of district leaders' beliefs about whether and in what ways current instruction aligns with argumentation. This is essential to explore because most teachers will need to shift their instruction to align with NGSS (Krajcik et al., 2014). Therefore, whether district leaders believe there are substantial differences between current instruction and argumentation is also crucial. One Likert scale item and two open-ended items were utilized to explore these beliefs (Table 3.2).

PCK

I utilized an assessment that measures PCK for argumentation through multiple-choice and open-ended items (McNeill et al., 2016). This instrument was piloted and revised over the course of two years, and used previously with teachers implementing an argumentation-focused curriculum. As discussed in chapter 2, this assessment was used because it measured the construct of interest and was easy to distribute to leaders across the country in states implementing the NGSS.

The PCK assessment utilized classroom vignettes to measure the two aspects of Shulman's (1987) definition of PCK: knowledge of student conceptions and knowledge of instructional strategies appropriate to these conceptions. These vignettes described teachers and students in classrooms engaged in argumentation. Research has shown that this type of classroom context is important in capturing PCK (McNeill et al., 2016). As discussed in the previous chapter, the items associated with these vignettes focused on the two elements of PCK as related to two conceptions essential to argumentation instruction: The first conception focuses on the structure of an argument – a claim supported by evidence and reasoning (McNeill & Krajcik, 2012) and the second conception focuses on the dialogical aspects of argumentation (Berland & Reiser, 2009; Driver et al., 2000). There were four vignettes, each with 4 multiple-choice questions and one open-ended question in this portion of the survey. Sample items for the structural conception and the dialogical conception are shown in Table 3.3. The full measure is included in Appendix A4.

Table 3.3

Sample PCK Survey Items

Argumentation Conception Targeted	**Vignette Excerpt**	**Sample Item**
Structural	*Maxwell*: Nora you only mentioned one of the fossils from the picture but not all of the plant fossils are on both landmasses. “Plant A” fossils are on both, but the “Plant B” ones are only on Landmass 2. *Nora*: So what? That doesn’t mean I’m wrong. Both plants didn’t necessarily grow before they separated. Maybe “Plant B” grew after the landmasses had already separated. *Maxwell*: I don’t agree. I think all of the plant fossils were from the same time.	One reason that Ms. Alves should consider this a successful argumentation interaction between Maxwell and Nora is: a. Nora and Maxwell displayed in depth fossil knowledge b. Maxwell demonstrated that he will stand by his claim c. Maxwell and Nora discussed only high quality evidence[1] d. Nora incorporated new evidence into her argument
Dialogic	Mr. Luongo asked his students to read an article and construct a scientific argument about whether *Elysia chlorotica*, a unique species of sea slug, should be characterized as a plant or animal. The article described the ways in which the slug exhibits characteristics of both plants, such as performing photosynthesis, and animals, such as being heterotrophs.	What do you think are the benefits and drawbacks to Mr. Luongo’s approach of having students debate a topic with multiple claims? Explain.

[1] Correct answer

Survey Administration

Recruitment

Recruitment focused on participants in the 13 states and the District of Columbia that had officially adopted NGSS as of May 2015. Participants were recruited through personal communication using information found on district websites, state listservs, and information provided by state-level science leaders. Specifically, I e-mailed district leaders in each of the 13 NGSS states and the District of Columbia inviting them to participate in the survey and asked state leaders in these states to forward the survey link to their district contacts. In exchange for participation, district leaders were offered a $50 Amazon gift card to compensate them for their time. In the e-mail invitation I also asked district leaders to forward the survey link to their colleagues.

Administration

The e-mail invitation contained a link to the online survey. The survey was administered through Qualtrics, an online survey construction and distribution site, so that district science leaders from states that have adopted the NGSS across the United States could easily participate.

Participants

Fifty-three district leaders participated in the survey, although three leaders did not complete the PCK instrument. Therefore, the sample size for the background and belief items is 53 and for the PCK portion is 50. The leaders were from a range of states that have adopted NGSS (Table 3.4). Specifically, participants responded from 9 states including California, Illinois, Kansas, Kentucky, Maryland, Nevada, New Jersey, Oregon, and Rhode Island, and Washington DC. To preserve the anonymity of the participants, these states are grouped by region for the reporting of the findings. The highest number of leaders were from midwest states, such as Illinois, and the fewest were from southern states, such as Kentucky. Leaders also reported the type of district in which they work, with the largest stating they are from suburban districts, and the fewest from rural districts (Table 3.4).

Table 3.4
Characteristics of Surveyed Leaders' Districts

Geographic Region	**Northeast**	**South**	**Midwest**	**West**
# of Leaders	18	7	19	9
Type of District	**Urban**	**Suburban**	**Rural**	
# of Leaders	21	28	4	

Thirty-three district leaders were female and 20 were male, and most reported their race as white (Table 3.5). These leaders possessed a range of experience as district administrators, with the greatest number having between two and five years of experience (Table 3.5).

Table 3.5
Characteristics of Surveyed Leaders

Gender	**Male**	**Female**				
# of Leaders	20	33				
Race[1]	**White**	**Hispanic or Lation**	**Black or African**	**Native American**	**Asian/Pacific Islander**	**Other**
# of Leaders	44	2	2	1	2	1
Years as a District Administrator	**1**	**2-5**	**6-10**	**11-15**	**16-20**	**More than 20**
# of Leaders	8	22	16	4	3	0

[1] Does not add up to 53 because leaders could select more than one category and 3 leaders chose not to provide their race.

The survey contained a list of possible job responsibilities that research has identified as being common for district science leaders (Whitworth et al., 2014). All of the leaders reported being responsible for disseminating information to teachers and for conducting professional development. Fifty-two leaders reported being responsible for curriculum design, 51 for analyzing data, and 27 for evaluating teachers. Leaders were also provided with a space to write additional responsibilities not in the list, and they included tasks such as working with principals, budgeting, and managing instructional materials. The survey also asked leaders about the content areas for which they are responsible. Twenty-one leaders indicated that they are only responsible for science, with the rest of the leaders selecting at least one additional content area such as math or social studies (Table 3.6).

Table 3.6
Professional Responsibilities of Leaders (n=53)

Job Responsibilities	**Curriculum Design**	**Disseminating Information to Teachers**	**Analyzing Data**	**Conducting Professional Development**	**Evaluating Teachers**
# of Leaders	52	53	51	53	27
Content Responsibilities	**Only Science**	**Mathematics**	**Social Studies**	**English/ Language Arts**	
# of Leaders[1]	21	19	13	13	

[1] Does not add up to 53 because leaders could select more than one of the non-science categories.

Interview Protocol Development

A semi-structured interview protocol was used to further explore a subset of the participants' beliefs about argumentation. The protocol contained one or two questions that targeted each of the belief categories used in the survey: typical science instruction, argumentation instruction, value of argumentation for students, and alignment of argumentation with current instruction (Table 3.7). These questions were designed to enable participants to more fully discuss their beliefs about the constructs. For this reason, several of the questions are identical to those used in the survey. The protocol is included in Appendix B.

Table 3.7
Belief Categories

Belief Category	Sample Interview Question
Beliefs about typical science instruction	What types of experiences do you think students need to have in the classroom to learn science?
Beliefs about argumentation instruction	What is the role of the teacher during argumentation instruction?
Beliefs about the value of argumentation	What benefits do you believe argumentation offers students in the science classroom? Explain.
Alignment of Argumentation with Current Science Instruction	Do you think the instruction in your district needs to change to align with the goals of argumentation? If so, in what ways? If not, why not?

Interview Administration

Interviews were conducted with 10 of the 50 survey participants who completed the entire survey. These individuals were recruited through the final survey question, which asked if they were willing to participate in a follow-up interview. From the pool of 35 participants who agreed to take part in a follow-up interview, 10 individuals were selected to represent a geographical range of participants and a range of responses on the Likert scale item targeting the fourth belief category, alignment of district instruction with argumentation. This type of geographical variability in states was important because state contexts could impact beliefs (McLaughlin & Talbert, 1993). In addition, a range of beliefs about alignment seemed essential because research suggests that current instruction is unlikely to align with NGSS (Krajcik et al., 2014). Therefore, I hypothesized that those district leaders who indicated agreement with the statement that instruction in their districts currently aligns with the goals of argumentation may have weaker understandings of argumentation. Table 3.8 shows the range of states and alignment responses of the participants who were interviewed, with 3 participants each from Northeastern and Western states, and 2 participants each from Southern and Midwestern states. Two participants strongly agreed that instruction in their districts was aligned with the goals of NGSS and two participants also strongly disagreed. Three participants agreed with this statement and three participants disagreed.

Table 3.8
Characteristics of Interviewed Leaders' Districts

Geographic Region	**Northeast**	**South**	**Midwest**	**West**
# of Leaders	3	2	2	3
Belief in Alignment	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
# of Leaders	2	3	3	2

This subset of district leaders in this study who participated in an interview differed slightly from the larger group that completed the survey. Specifically, the distribution of male and female leaders was even in the interviewed group while the larger group had more female participants than male (Table 3.9). In addition, a greater proportion of the interview participants had between six and 10 years of experience as a district administrator than in the larger survey group. Similar to the survey group, most participants in the interviews were white. The interview questions focused on the same constructs as the survey, therefore despite some differences between the larger sample and this subset, interviewed leaders' beliefs did not play a greater role in the data analysis than the survey responses.

Table 3.9
Characteristics of Interviewed Leaders

Gender	**Male**	**Female**				
# of Leaders	5	5				
Race	**White**	**Hispanic or Lation**	**Black or African**	**Native American**	**Asian/Pacific Islander**	**Other**
# of Leaders	9	1	0	0	0	0
Years as a District Administrator	**1**	**2-5**	**6-10**	**11-15**	**16-20**	**More than 20**
# of Leaders	2	3	5	0	0	0

Interviews were scheduled at a time that was mutually convenient for the participants and interviewer. All interviews took place on the telephone and were audio recorded. The interviews were subsequently transcribed for analysis. The interviews took on average 35 minutes to complete. Participants in the interviews were offered a $50 Amazon gift card to compensate them for their time.

Analysis of Survey Scales

Belief Items

Although the items were designed using theoretical understandings of argumentation, this was a new instrument, and participants may not have made sense of the items in the ways they were intended. Therefore, exploratory Principal Component Factor Analysis techniques seemed most appropriate to identify interrelated variables and enable the creation of more manageable constructs (Hair et al., 2010). This analysis resulted in two factors, each with a Cronbach's Alpha greater than 0.8 (Table 3.10): beliefs about NGSS-aligned instruction and argumentation benefits, and beliefs about typical science instruction. I created each factor by summing the individual items and dividing by the total number of items. Dividing by the total number of items allowed the factors to maintain the same scale (i.e. 1 = Strongly Disagree to 4 = Strongly Agree), which increased the ease of interpretation.

The first factor, NGSS-aligned Instruction and Argumentation Benefits, included items from two of the original belief constructs, argumentation instruction and value of argumentation for students (see Tables 3.1 and 3.2). As such, this factor focuses on leaders' beliefs about instruction for argumentation, such as students using evidence to support ideas, *and* the benefits of argumentation instruction, such as improved literacy skills. While the instruction of and the value of argumentation for students may appear to be separate constructs, it is logical that they would combine into one factor because they both represent leaders' beliefs about student engagement in argumentation in the science classroom.

The Typical Science Instruction factor included only items from the original typical science instruction construct. Similar to the first factor, this makes theoretical sense. These items all refer to typical methods of science instruction that represent the types of teaching and learning not aligned with the goals of the NGSS, such as teachers presenting information and a focus on the scientific method.

Table 3.10
Survey Belief Factors

Factor Name	**Cronbach's Alpha**	**Survey Items**
NGSS-aligned Instruction and Argumentation Benefits (20 items)	0.951	• During class discussions students should persuade each other of their ideas. • Scientific argumentation is an effective way to develop students' critical thinking skills. • Critiquing texts and ideas is an important part of science learning. • Scientific argumentation is an effective way to develop students' reasoning and problem-solving

		skills. • Science instruction should engage students in using science ideas to explain evidence. • Scientific argumentation is an effective means by which to develop students' language skills (reading, writing, and speaking). • Students should consider multiple scientific claims as part of learning science. • Scientific argumentation is an effective way for students to learn and practice literacy strategies. • Scientific arguments are best constructed by allowing students to build on each other's ideas. • Scientific argumentation is an effective way to increase students' interest in science. • Students should use data to support or refute scientific claims. • Scientific argumentation is an effective way to help students consider multiple views about science. • During class discussions, students should question each other's ideas. • Scientific argumentation is an effective way to encourage student participation in class discussions. • Engaging students in using scientific principles to explain evidence is an important part of science instruction. • Scientific argumentation is an effective way for students to learn science content. • Scientific argumentation skills that students learn, develop, and use are applicable outside the science classroom. • Student-to-student interactions are an important part of scientific argumentation in the classroom. • Scientific argumentation is an effective way to increase students' understanding of how scientists work. • Hands-on activities are the best way for students to learn science.
Typical Science Instruction (8 items)	0.805	• The scientific method should be a focus of science instruction. • Teachers should present scientific information to students. • Class discussions are most effective when they occur after students have learned the science content.

	• Teachers should always provide feedback to students after they speak in class. • Laboratory activities are most effective for students after they have learned specific content. • Teachers should explain an idea to students before having them consider evidence that relates to that idea. • At the beginning of instruction of a new science idea, students should be provided with definitions for new scientific vocabulary that will be used.

PCK Items

The number of correct multiple-choice answers on the PCK instrument was tallied for each district leader and the open-ended items were coded using previously designed coding schemes (McNeill et al., 2016). The coding schemes and reliability are described in more detail below. Each district leader was subsequently given a total PCK score and a score for each of the two PCK conceptions, structural and dialogical.

Alignment Belief Item

The final Likert scale item asked leaders whether they strongly agreed, agreed, disagreed, or strongly disagreed with the statement "Overall, the science instruction in my district is closely aligned with the goals of scientific argumentation." I conducted three ANOVAs to determine if there were statistically significant differences between the means for Factor 1, Factor 2, and total PCK scores, and the level of agreement on this item. For the areas of statistical significance, I ran post-hoc Tukey tests to determine where the significant differences occurred.

Development of Coding Schemes

There are three qualitative data sources in this study: open-ended survey belief items, open-ended survey PCK items, and interview responses. The coding schemes for each open-ended survey belief item are included in Tables 3.11-3.14 and an abbreviated sample PCK coding scheme in Table 3.15. The full PCK coding schemes are contained in Appendix C. As this coding was an iterative process (Miles & Huberman, 1994), the preliminary codes were revised after the data was collected and during their analyses. Two coders coded 20% of the responses for each open-ended item and interrater reliability was calculated by percent agreement. The average interrater reliability for the belief items was 87% and 85% for the PCK items. Disagreements were resolved through discussion. After these discussions, and refinement of the coding schemes, one coder coded the remainder of the responses. For both the belief and PCK items, I will first describe the coding schemes and then I will discuss how those codes were utilized to address the specific research questions in this study.

Open-Ended Belief Items

The open-ended question on the survey for the first two categories of belief (Table 3.4) was: What do you think good science instruction looks like? I constructed the coding scheme to target: 1) the specific science practices described in the NGSS (NGSS Lead States, 2013); 2) features of science instruction that align with the goals of the NGSS; and 3) features of science instruction that do not align with the NGSS. Table 3.11 includes the 12 total codes for this coding scheme that refer to these three characteristics.

For the first characteristic, the specific science practices, I developed codes that referred to the three groupings suggested by McNeill, Katsh-Singer, and Pelletier (2015) of 8 NGSS science practices: investigating practices, sensemaking practices, and critiquing practices (Figure 3.1). The three investigating practices focus on the ways that students design and implement methods of data collection. The three sense-making practices engage students in the analysis of data and the construction of representations based on data, such as models, to explain the phenomena under study. The two critiquing practices focus on students critiquing such representations as well as texts. I chose to utilize these three categories of practices to make identifying the practices in leaders' responses more manageable. Consequently, the first three codes in the coding scheme in Table 3.11 are investigating practices, sensemaking practices, and critiquing practices.

Investigating Practices	**Sense-making Practices**	**Critiquing Practices**
• Asking questions • Planning and carrying out investigations • Using mathematical and computational thinking	• Developing and using models • Analyzing and interpreting data • Constructing explanations	• Engaging in argument from evidence • Obtaining, evaluating and communicating information

Figure 3.1: *Three Categories of NGSS Science Practices*

For the next characteristic, features of science instruction that align with NGSS, I utilized descriptions in the NGSS (NGSS Lead States, 2013) and the *Framework* (NRC, 2012) that align with instruction focused on science practices, such the use of evidence and a connection to the natural world. There are five codes for this characteristic in Table 3.11: student-directed, collaborative, student talk, evidence, and natural world.

For the final characteristic, features of typical science instruction, I considered types of instruction that do not align with the NGSS. I developed codes to describe science instruction that represent the type of teaching that the NGSS aims to reduce, such as teachers presenting information to students (NRC, 2012). The four codes for this characteristic are: inquiry, scientific method, hands-on, and presenting.

Across the entire coding scheme, district leaders could receive multiple codes for their responses. For example, one district leader described good science instruction as "Students listening to and responding to the ideas of others, towards consensus on science explanations and models" (Table 3.11). This response was coded as "sensemaking practices" for the mention of the sensemaking practices of scientific explanations and modeling (Figure 3.1), and as "student talk" for the mention of students listening to and responding to the ideas of others.

Table 3.11

Coding Scheme for Open-Ended Survey Question: What does good science instruction look like?

	Code	**Definition**	**Sample Response**
1) Three groups of NGSS Science Practices	Investigating Practices	Leader mentions by name or discusses features of at least one of the three Investigating Practices: 1. Asking questions 2. Planning and carrying out investigations 3. Using mathematics and computational thinking	"Students engage in research and investigation where they collect and analyze data to construct explanations about phenomena."
	Sense-making Practices	Leader mentions by name or discusses features of at least one of the three Sense-making practices: 1. Developing and using models 2. Analyzing and interpreting data 3. Constructing explanations	"Good science instruction should engage students in understanding the world by constructing and using scientific models to describe, to explain, to predict and to control physical phenomena."
	Critiquing Practices	Leader mentions by name or discusses features of at least one of the two Critiquing Practices: 1. Engaging in argument from evidence 2. Obtaining, evaluating and communicating information	"Engaging in argument from evidence as they interpret their observations"

2) Features of Instruction Aligned with NGSS	Student-directed	Leader discusses the importance of students leading or taking charge of their science experiences OR discusses that it should not be teacher-directed or teacher led.	“Good science instruction requires the teacher to act as a coach and the students are developing their investigations based on content through their own questioning.”
	Collaborative	Leader discusses students working collaboratively in pairs, groups, or other multiple-student formations.	“Students regularly work in collaborative groups to accomplish meaningful tasks related to natural and designed phenomena.”
	Student Talk	Leader discusses the importance of engaging students in science talk to learn science or discusses the importance of students talking to each other, not solely the teacher.	“Students listening to and responding to the ideas of others, towards consensus on science explanations and models.”
	Evidence	Leader discusses the importance of evidence or data in science.	“Students…analyze and draw conclusion from data that they collect or are given and would engage in discussion regarding these findings/conclusions.”
	Natural world	Leader discusses science as focusing on the natural world or nature or the world around us.	“Good science instruction provides students with an opportunity to understand and explain phenomena by questioning, investigating, and concluding.”
3) Features of Typical Science Instruction	Inquiry	Leader uses the term “inquiry” to describe good science instruction.	“Use of summative performance tasks that map to inquiry based activities during instruction.”
	Scientific Method	Leader uses the term “scientific method” when describing good science instruction.	“A balance of focused content instruction (building content knowledge over time) and process (e.g. scientific method).”

Hands-on	Leader discusses the importance of "hands-on" elements of science instruction, or kids "doing" science or activities.	"For young children, it is important that science instruction be very exploratory and hands-on."
Presenting	Leader discusses the importance of the teacher, a video, or a textbook presenting the science concepts to students.	"There does need to be some delivery of instruction but that information should lead to some student-centered activity or investigation."

The open-ended survey questions for the third belief category, value of argumentation for students, were: What do you believe are the benefits to students, if any, of engaging in scientific argumentation? and What do you believe are the drawbacks to students, if any, of engaging in scientific argumentation? The coding schemes were adapted from McNeill et al.'s (2013b) study of factors that impact argumentation instruction. Categories based on the findings of additional researchers related to teacher beliefs were also added. Table 3.12 contains the coding scheme for the question about benefits and Table 3.13 contains the coding scheme for the question about drawbacks. The coders added the final category to the coding scheme in Table 3.13, teacher skill, during the data analysis to capture a response not previously predicted. Specifically, we found that several district leaders stated that there were no drawbacks to students *unless* a teacher did not have sufficient skill or expertise to engage them in argumentation. It seemed important to recognize this nuance, especially for district leaders charged with supporting teachers, and therefore both coders agreed to include this new code. Leaders could receive multiple codes for their responses.

Table 3.12

Coding Scheme for Open-Ended Survey Question: What do you believe are the benefits to students, if any, of engaging in scientific argumentation? Why do you see these as benefits?

Code	**Definition**	**Sample Response**
None	Leader states that there are no benefits to students of engaging in argumentation.	No leaders received this code.
Literacy (McNeill et al., 2013b)	Leader discusses argumentation as supporting students in developing improved reading, writing, or communication skills.	"Scientific argumentation can be linked to argumentative writing across curricula and help students develop logical arguments in support of ideas."
Critical thinking (McNeill et al., 2013b; Sampson & Blanchard, 2012)	Leader discusses argumentation as improving students' abilities to think critically, solve problems, apply ideas, or analyze situations.	"Applying and strengthening literacy skills and meta cognition by communicating thinking and thought processes, and considering ideas from others using discussions, texts, media, etc. These are evidence of higher level thinking, and well align with goals of college and career readiness."
Evidence (McNeill et al., 2013b)	Leader discusses argumentation as necessitating a focus on the use of evidence.	"This is the way that true science is done: collect data, present a reasonable argument. Defend the argue net with data and present your evidence to a wide range of stakeholders."
Multiple Views (McNeill et al., 2013b)	Leader discusses argumentation as exposing students to multiple views about science or engaging students in considering different perspectives.	"Students are given a chance to prove their thoughts and disprove others. This allows students to consider others' ideas and possibly change their own thinking."
Critique (McNeill et al.,	Leader discusses argumentation as involving	"Evaluation of peers and teacher provided evidence

2013b)	students in the process of critique. They may discuss this in terms of critiquing peers, text, investigations, or other sources.	and viewpoints also develops critiquing skills in students that are difficult to isolate in other subject areas."
Science Content (Sadler, 2006)	Leader discusses argumentation as supporting students in learning science ideas more deeply.	"Students apply their content knowledge, which helps them make sense of scientific phenomenon."
How Scientists Work (NRC, 2012)	Leader discusses argumentation as exposing students to the ways that scientists engage in science or engaging students in work of scientists.	"It is an authentic scientific practice, and students need to participate in versions of authentic science practices to develop accurate conceptions of and concepts in science."

Table 3.13
Coding Scheme for Open-Ended Survey Question: What do you think are the drawbacks for students, if any, of engaging in scientific argumentation? Why do you see these as drawbacks?

Code	Definition	Sample Response
None	Leader states that there are no drawbacks to engaging students in argumentation.	"I don't really see any drawbacks to the use of scientific argumentation in the classroom. There are many options to address various concerns and adaptations can be made to meet the needs of all students."
Confusing for students (Simon et al., 2006; Osborne et al., 2004)	Leader states that argumentation can cause students to be confused. They may reference content, science knowledge, or other sources of confusion.	"It can further deepen their misconceptions about phenomenon and thus making it more difficult to correct their naive thoughts."
Too difficult for some students (Katsh-Singer et al., 2014; Zohar et al., 2001)	Leader states that argumentation is a drawback because it is too hard for some types of students.	"Some students are not open to it. Some students are not prepared to engage in it. They do not practice it outside of the science classroom, and it may cause discomfort if it challenges closely held beliefs."

Takes too much time (Sampson & Blanchard, 2012)	Leader states that argumentation takes too much time away from other science learning or is too time consuming an experience overall.	“Time. There must be a balance to ensure students have time to learn about all core ideas and content.”
Teacher Skill	Leader states that argumentation will only have drawbacks is the teacher lacks sufficient pedagogical skill.	“Teachers must be trained to conduct classes in this format, as opposed to the format that most of them learned in. Students will suffer if the learning environment deteriorates and the issues at hand are not addressed and they are able lose focus and to drift off task.”

The open-ended questions for the final belief category, alignment of argumentation with current science instruction in the district, were: In what ways does the instruction of science teachers in your district align with scientific argumentation? and In what ways does the instruction of teachers in your district not align with scientific argumentation? The coding scheme for these responses focused on the accuracy of leaders’ descriptions of argumentation (Table 3.14). This allowed for a further analysis of whether district leaders accurately conceptualize the ways that argumentation is similar and different than typical science instruction. For this coding scheme, leaders could receive one code to characterize the accuracy of their response (accurate, inaccurate, vague, or off-topic) and an additional code of “typical instruction.” This final code was included to determine whether leaders, in discussing the alignment or lack thereof of instruction in their districts with argumentation, also discussed a shift away from traditional instructional methods.

Table 3.14

Coding Scheme for Open-Ended Survey Questions: In what ways does the science instruction of teachers in your district align with the goals of scientific argumentation? and In what ways does the science instruction of teachers in your district not align with the goals of scientific argumentation

Code	**Definition**	**Sample Response**
Accurate Argumentation	Leader accurately describes at least one key aspects of argumentation such as: o Student-to-student talk, debate or questioning o Supporting claims, ideas or arguments with evidence o Critiquing/evaluating ideas, claims, models, explanations, or texts o Persuading or convincing peers	“Teachers are beginning to teach students how to reason scientifically by supporting their claims with evidence. Students also engage in debates pertaining to controversial topics (i.e. nuclear energy, genetic technology).”
Inaccurate Argumentation	Leader describes argumentation without including any of the above features or includes one of the above features along with an inaccurate feature, such as students reading texts to learn information.	“Students are asked to challenge their beliefs and find ways to defend the authenticity of these beliefs (i.e. gravity acts down, mass is conserved in a chemical reaction).”
Vague Argumentation	Leader provides a vague response that is related to argumentation. They may use the term “argument” but the leader does not define it or explain what it is.	“This varies from teacher to teacher and course to course. In tested areas such as AP curriculum pressure slants the approach heavily towards content and away from student oriented processes such as argumentation.”
Off Topic	Leader’s response does not address argumentation.	“We are just beginning our work with the Next Generation Science Standards; however, we are already strong in the belief that science should be more focused on process than content. We are beginning to

		use engineering design models.”
Typical Instruction	Leader accurately describes typical science instruction, such as teacher presenting ideas, and states that this does not align with argumentation.	“Our legacy curriculum is based on low level memorization of facts rather than engaging in authentic scientific practices.”

Open-Ended PCK Items

As previously discussed, responses to the open-ended PCK items were coded using rubrics adapted from McNeill et al. (2016). Each open-ended item had a separate rubric to reflect the unique nature of the vignette and the PCK conception targeted. Table 3.15 shows a sample open-ended question along with a condensed version of the two-layered rubric for assessing responses. All of the full rubrics are included in Appendix C. The question in Table 3.15 was related to the dialogical PCK conception and focused on district leaders’ knowledge about effective strategies for helping students engage in oral argumentation. The two aspects to the rubric were necessary to capture both the instructional strategies district leaders believed are effective, and also their rationales for using these strategies. Since PCK is often considered a hidden type of knowledge (Kind, 2009), assessing district leaders’ reasoning can help make their PCK more visible. The total number of points earned for each open-ended response was added to the leaders’ scores for the multiple-choice items.

Table 3.15

Sample Coding Scheme for Open-Ended PCK Item: What are two strategies that you believe are effective for helping students engage in oral argumentation? Explain why these strategies are effective.

Category	Level 0	Level 1	Level 2
Strategies for engaging in oral argumentation	The leader does not address this topic OR The leader provides strategies that will not support engaging students in debate about a claim OR The leader provides strategies that solely focus on the structure of arguments (CER) and not how to use this structure to engage in debate	The leader states one appropriate strategy for engaging students in oral argumentation. (The leader may state one appropriate strategy and one inappropriate strategy.)	The leader states two appropriate strategies for engaging students in oral argumentation.
Rationale for incorporating strategies	The leader does not address this topic OR The leader provides a rationale that is not appropriate for argumentation OR The leader discusses a big idea about argumentation that is unrelated to the strategies s/he provided in response to this question.	The leader states a rationale that supports only **one** of the strategies provided in the response. This rationale should include one of the following: • Student-to-student talk • Evaluating multiple claims • Seeing there is not one right answer • Trying to convince other students of their claim or argument	The leader states one rationale that supports **both** strategies provided in the response OR The leader states **two different** rationales, each supporting a different strategy provided in the response These rationales should include one of the following: • Student-to-student talk • Evaluating multiple claims • Seeing there is not one right answer • Trying to convince other students of their claim or argument

Data Analysis

After the factors were developed, the open-ended items coded, and the PCK multiple-choices responses assessed, I began the process of developing themes to characterize the findings using both the survey and interview results. I looked across the data sources to notice, evaluate the plausibility of, and form categories of patterns in the data (Miles & Huberman, 1994). During this process I wrote memos to document the evolution of these patterns, which I discussed with another coder (Charmaz, 1999). In addition, both coders actively sought out confirming and disconfirming evidence to support or challenge the emergent themes (Cresswell & Miller, 2000). This iterative process resulted in five themes that represented the findings for the three research questions.

For Research Question 1, three themes emerged to describe district leaders' beliefs about science teaching and learning and about scientific argumentation. For Research Question 2, one theme emerged to characterize leaders' PCK for argumentation. For Research Question 3, one theme emerged to describe leaders' beliefs about the alignment of argumentation with teachers' science instruction in their districts. I will now describe in more detail the process of data analysis that resulted in these themes for each research question.

Research Question 1

I began to develop the themes for research question 1 by looking at the results from the factor analysis. I examined the means for each of the factors and counted the number of leaders whose mean factor scores were below 2.5, closer to "disagree" than "agree," and above 2.5, closer to "agree" than "disagree." I next examined the codes for open-ended survey item that asked leaders to discuss what they believed good science instruction looks like. I counted the number of leaders who received only NGSS–aligned codes, leaders who received only typical instruction codes, and leaders who received both. The two coders then looked at the interview transcripts for the first interview question to examine the ways in which these leaders discussed effective science instruction. The coders created tables to compare the factor scores, survey codes, and interview quotes to inform the development of the theme.

While developing the first theme, I noticed frequent mentions of evidence in the open-ended survey responses and interview transcripts. Therefore, I looked more closely at the second open-ended item, about leaders' beliefs of argumentation benefits for students, to see how often leaders discussed evidence. I counted the number of codes given for each benefit in the coding scheme, and saw that leaders believed in a range of educational benefits for students, but student use of evidence was the most frequent code. I also noted that only one leader's response received the critique code. I began to develop two themes, one around evidence as a benefit of argumentation and one about critique as a part of argumentation, since the "critiquing practices" code was prevalent in the first open-ended item. However, in examining leaders' responses to this first open-ended item, I saw that while their responses were coded for references to "critiquing practices" almost as frequently as "sensemaking practices" and "investigating practices," all but one response was given this "critiquing practices" code for the mention of a critiquing practice, argumentation, and not for describing critique as part of effective science education for students. The two coders then looked at the interview transcripts to see whether and in what ways leaders discussed evidence and the other benefits from the survey in their descriptions of the benefits of argumentation for students. We saw references to multiple benefits, especially evidence, but only one mention of critique in the interview transcripts. Therefore, I collapsed the two themes into one.

A third theme emerged from an analysis of data from the first factor and the interview transcripts. As previously mentioned, the Likert scale item referring to hands-on science was intended to reflect typical science instruction. However, it was included in the first factor about leaders' beliefs of effective science instruction, not the second factor about typical instruction (Table 3.15). I looked more closely at the leaders' choices for this Likert scale item and counted the number of leaders who selected "agree" or "strongly agree," and those who selected "disagree" or "strongly disagree." Since one of the interview questions asked leaders to define hands-on science (Appendix B), the two coders then examined the interview transcripts. Eight of the ten leaders' interview responses to this question suggested that they were expanding on the traditional activity-based definition of hands-on science (Zembal-Saul, 2009) to include some of the science practices. As such, a third theme emerged around hands on science.

Research Question 2

This research question focused on leaders' PCK for argumentation. I calculated a total PCK score and PCK scores for each argumentation conception for each leader. I also found the mean scores for the multiple-choice and open-ended items for each conception. I looked at the distributions of leaders' choices for the multiple-choice items in each conception, and also at the coding for the open-ended items, to find patterns to explain the scores on this instrument. Specifically, some district leaders appeared to have challenges around evidence and reasoning on the multiple-choice items. Therefore, I examined the open-ended items to determine the ways in which leaders described evidence and reasoning. Since leaders also appeared to struggle with the dialogical conception, especially items referring to critique, I looked at the two open-ended items for this conception to explore how leaders discussed strategies for supporting students in discourse that includes critique. This resulted in the fourth theme around PCK.

Research Question 3

This research question focused on leaders' beliefs about the alignment of current instruction in their districts with argumentation. As previously described, I conducted ANOVAs to determine whether there were statistically significant differences between the alignment beliefs of the leaders and their means for Factor 1, Factor 2, and the total PCK scores. Then, I considered the practical implications of the areas of statistical significance. I next examined the codes for the final two open-ended belief items in which leaders were asked to discuss the ways current instruction aligns and does not align with argumentation. Leaders' responses were coded based on the accuracy of their descriptions of argumentation as well as whether they mentioned a need to shift away from typical instruction. I counted the number of leaders whose responses were coded as accurate, inaccurate, vague, and off-topic and also the number of leaders who received the typical instruction code. The two coders then analyzed the interview transcripts to determine the ways in which leaders discussed alignment. We saw that leaders discussed various contextual factors that appeared to impact their beliefs about argumentation in their districts. I then went back to the survey to count the number of leaders who mentioned similar factors. This resulted in the final theme about alignment.

Summary

This dissertation focuses on the beliefs and PCK of district science leaders about scientific argumentation. The methods described in this chapter have been selected to explore these constructs in multiple ways while reflecting the sense-making theoretical framework that guides this research. Specifically, the data analysis provides insights into the ways that district leaders conceptualize argumentation as similar or different than typical science instruction. In addition, it explores the extent of their knowledge of effective argumentation instruction for students.

CHAPTER 4: RESULTS

In this chapter I present the results from the analyses of the survey and interview data. The results are organized by themes that pertain to each research question (Table 4.1). Specifically, three themes emerged related to research question 1: the first about district leaders' beliefs about effective science instruction, the second about the benefits of argumentation for students, and the third about the term "hands-on" in science education. For research question 2, one theme emerged to characterize leaders' PCK for argumentation. For research question 3, one theme emerged to describe district leaders' beliefs about current argumentation instruction in their districts. I next describe the themes and discuss the evidence from the surveys and interviews that support them.

Table 4.1
Research Questions and Themes

Research Question	Data Sources	Themes
1. What are district science leaders' beliefs about the differences between scientific argumentation and typical science instruction? a. What are district science leaders' beliefs about effective science instruction? b. What are district science leaders' beliefs about the teaching and learning of scientific argumentation?	Survey: belief instrument Interviews	1. All district leaders believed that high quality science instruction engages students in the practices of science; however, just under half described effective instruction as including typical methods. 2. District leaders described multiple benefits of argumentation for students, including a focus on evidence, but almost never discussed the role of critique. 3. District leaders believe "hands on" science can involve students in the practices of science.

2. What are district leaders' PCK for scientific argumentation?	Survey: PCK instrument	4. District leaders displayed a range of PCK for argumentation, with many demonstrating difficulty differentiating between evidence and reasoning and a limited understanding of the role of critique.
3. What are district leaders' beliefs about the alignment of argumentation with current science instruction in their districts?	Survey: belief instrument Interviews	5. District leaders' beliefs about the level of alignment of current instruction with argumentation appeared to be impacted more by beliefs about local conditions than their PCK or beliefs about argumentation.

Theme 1: District leaders believed that high quality science instruction engages students in the practices of science; however, just under half described effective instruction as including typical methods.

The results of the analyses of the beliefs items in the survey indicate that district leaders believed effective science instruction incorporates goals and strategies that align with NGSS practice-based instruction, especially scientific argumentation. However, some leaders also believed that typical instructional strategies were part of effective science instruction. As discussed in chapter 3, the exploratory principal component factor analysis resulted in two factors, each with a Cronbach's alpha greater than 0.8: beliefs about NGSS-aligned instruction and argumentation benefits, and beliefs about typical science instruction (Table 4.2).

Table 4.2
Means and Standard Deviations of Belief Factors

Belief Factor	Mean (SD)
NGSS-Aligned Instruction and Argumentation Benefits[a]	3.50 (0.13)
Typical Science Instruction[a]	2.26 (0.20)

[a] Leaders' choices: 1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

The mean for the first factor, beliefs about NGSS-aligned instruction and argumentation benefits, was 3.5. The means for 52 of the 53 leaders (98%) for these items were between “agree” (3.0) and “strongly agree” (4.0) that the descriptions in these Likert scale items aligned with their beliefs about effective science instruction. With one exception, these items described either instructional strategies associated with the NGSS science practices, such as “Students should consider multiple scientific claims as part of learning science,” or educational benefits for students engaged in argumentation, such as “Scientific argumentation is an effective way for students to learn science content.” The exception was an item that was intended to describe typical science instruction. This item was “Hands-on activities are the best way for students to learn science.” As I will discuss in the third theme for this research question, leaders’ discussions in their surveys and interviews about the term “hands-on” in science indicated that they can define this term in varied ways, including as aligning with science practices. As such, it makes theoretical sense that this item was included in the first factor.

The mean for the second factor, beliefs about typical science instruction, was 2.26. This is between “disagree” (2.0) and “agree” (3.0). Twelve leaders’ (23%) means for this factor were greater than 2.5, closer to “agree” than “disagree.” This suggests that these leaders believed that the strategies described, such as “teachers should present scientific information to students,” described effective science instruction. The remaining 41 leaders’ (77%) means were below 2.5, closer to “disagree” than “agree.” This suggests that they may not have believed such strategies were part of effective science instruction for students.

However, the analyses of the open-ended survey item targeting leaders' beliefs about effective science instruction suggested that a greater number of leaders may have believed that effective science instruction includes typical methods. This open-ended item was coded using 12 codes that targeted three characteristics: NGSS science practices, features of instruction aligned with the NGSS, and features of instruction in typical science classrooms (Table 3.11). Twenty-four leaders (45%) received either typical instruction codes or NGSS-aligned *and* typical instruction codes, with most of these leaders receiving both types of codes (18 leaders, 34%). In addition, 9 leaders (17%) did not receive any codes because their responses were vague. Only 20 leaders' (33%) responses received only NGSS-aligned codes (Figure 4.1). This suggests that a larger number of leaders than indicated in the quantitative data viewed science instruction as including typical instructional strategies.

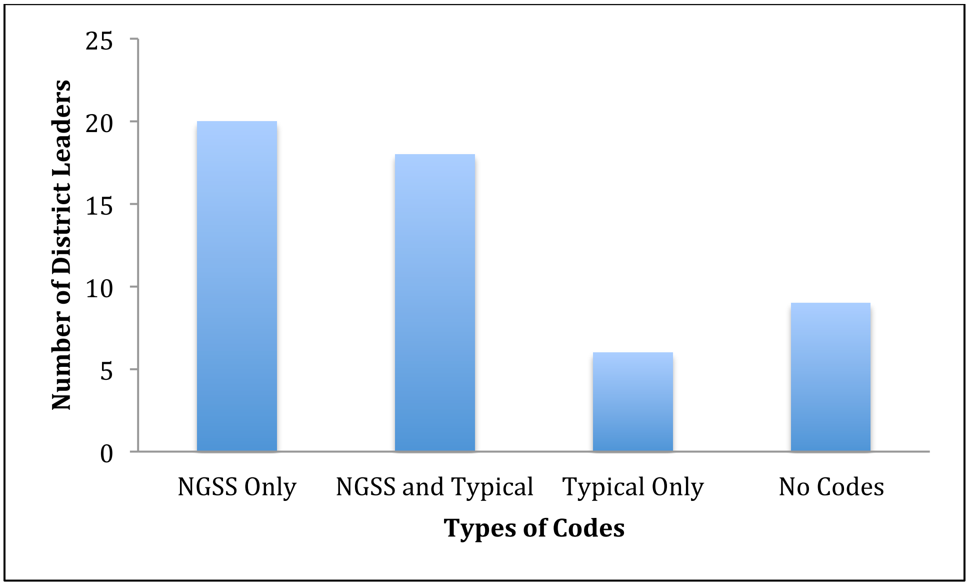


Figure 4.1: *Distribution of Codes for Open-Ended Survey Item: What does good science instruction look like? (n = 53)*

The leaders who received only NGSS-aligned codes described science instruction as either incorporating the practices of science, such as investigating or features of NGSS-aligned instruction, such as student collaboration. For example, DL (District Leader) 12 described effective science instruction as "Students making sense of data/phenomenon/observations and engaging in argument from evidence as they interpret their observations." This response was coded as "sensemaking practices" for the mention of students making sense of data/phenomenon/observations and "critiquing practices" for discussing engaging in argument from evidence. This response was also coded as "evidence," a key feature of NGSS-aligned instruction, because of the inclusion of the terms "data" and "evidence." This DL did not mention any typical instructional methods such as teachers presenting information or the use of the scientific method.

Similarly, DL24's response received only NGSS-aligned codes. DL24 wrote in the survey that during effective science instruction "Students engage in research and investigation where they collect and analyze data to construct explanations about phenomena." This response was coded as "investigating practices" for the reference to students conducing investigations and "sensemaking practices" for the description of students analyzing data and constructing explanations. This response also received the "evidence" code for the mention of data. As with DL12, DL24 did not include references to any typical instructional methods. Of the 20 leaders whose responses received only NGSS-aligned codes, 15 leaders' responses were coded for references to both science practices and features of NGSS-aligned instruction, with three leaders' responses only coded for features, such as student collaboration, and two responses only coded for science practices, such as critiquing practices.

Eighteen leaders' responses to the open-ended items were coded with both NGSS and typical instruction codes. These responses included references to the types of instruction prioritized by NGSS *and* descriptions of more typical, teacher-centered instruction. For example, DL33 wrote:

> *I feel that good instruction presents a basic idea or concept to students. Students then take that idea, internalize it and design experiments with it to deepen their understanding.*

This response was coded as "investigating practices" for the mention of students designing experiments. However, this response was also coded using the typical instruction code of "presenting" for the belief that good instruction includes presenting information to students. This leader believed that teachers presenting information to students has a role in science classrooms along with more NGSS-aligned aspects, such as students gathering data.

Another leader who received both NGSS-aligned and typical instruction codes was DL35. He wrote, "A mix of styles are necessary for success. Some topics are better taught as a lecture, some are better when they are student-led, some are good for projects, etc. Passion for the subject and designing activities that engage students are the most important." This response was coded as "student directed" for the mention of students leading, one of the features of NGSS-aligned instruction, and also with the typical science code "presenting" for the reference to lecture. This suggests that similar to the other leaders who received both types of codes, DL35 believed that elements of NGSS-aligned instruction are compatible with more typical methods such as teachers presenting information to students.

A small group of leaders, six, had responses that were coded with only typical instruction codes. For example, DL52 wrote that science instruction should be "A balance of focused content instruction (building content knowledge over time) and process (e.g., scientific method) and inquiry methods should be included daily." This response displayed none of the elements of NGSS-aligned instruction or science practices in the coding scheme and instead utilized terms, such as "scientific method" and "inquiry," that signal a view of science instruction that is unlikely to align with NGSS. Such terms, such as "inquiry," can have a range of meanings (Anderson, 2002) and may not refer to instruction that prioritizes the science practices (Bybee, 2011, NRC, 2012). Similarly, D27 wrote, "It should involve inquiry, students should be motivated to explore ideas and concepts outside of the classroom." This response was also coded as "inquiry" for the use of this term. As with DL52, DL27 did not reference any specific NGSS-aligned features of instruction or science practices, suggesting that this leader's beliefs did not align with the goals of the NGSS.

A final group of nine leaders received no codes because their descriptions of effective science instruction did not include any of the science practices, features of NGSS-aligned instruction, or features of typical instruction in the coding scheme. For example, DL38 wrote, "Good science instruction is a combination of the above statements. Science teachers have to have the basics down...classroom management and many opportunities for formative assessment." This response does not sufficiently elucidate DL38's beliefs about science instruction so it could not be coded.

As the responses to the first open-ended belief items demonstrated, a large group (66%) of leaders did not believe effective science instruction only included elements prioritized by the NGSS. Of this group, 18 leaders believed that science instruction can include *both* NGSS elements and typical methods, while six leaders did not explicitly mention aspects of the NGSS at all. Nine leaders' descriptions were too vague to code, however their responses also did not include any NGSS elements or science practices.

The interviews that were conducted after the survey administration provide greater insight into how a subset of leaders viewed effective science instruction and confirm much of the findings from the survey data. Leaders were asked to discuss effective science instruction and were prompted to explain the roles of the teacher and students in such classrooms (Appendix B). For seven out of the 10 leaders, their beliefs about science instruction in the interviews aligned with their survey responses. For example, DL04 received only NGSS-aligned codes for her survey response describing effective science instruction. She wrote "Student centered with problem solving, creating possible solutions, testing them, and redesigning, along with evidence based arguments supporting or disproving their investigations/claims." She discussed in her interview what occurs in a classroom in which such argumentation is happening. "The discourse I envision is the students, majority, have a majority of the conversation and they are using evidence to support what they're saying and they're offering that to another classmate and then that classmate can rebuttal or agree or build upon." Similar to her survey response, DL04 accurately described instruction aligned with the goals of the NGSS. The NGSS emphasize the need for students to engage discourse with each other as part of scientific argumentation (NRC, 2012). Similarly, six additional interviewed leaders described their beliefs about effective instruction in ways that aligned with their survey responses.

For three of the 10 leaders interviewed, however, their open-ended survey responses did not fully align with their interview responses. For two of these leaders, DL38 and DL45, the interviews were instrumental in clarifying their beliefs about effective science instruction. Both leaders' survey responses were vague and did not receive any codes. However, in his interview, DL38 described effective science instruction as including both aspects of the NGSS and typical instructional methods, and DL45 described only NGSS-aligned instruction. For example, DL45 wrote in his survey that effective science instruction means "Three dimensional, content, practices, and crosscutting concepts. Students are engaged in science just as a scientist in the real world." This suggests that DL45 believes NGSS is important, but the lack of any specific mention of science practices or elements of instruction meant that his response could not be coded. However, his interview implied that he believed good instruction aligns with the features of the NGSS. He said:

> *It's authentic. Provides them investigation where they're uncovering content, and not just handling investigations, but also include the time to communicate to one another, whether it be verbally or in writing, to access information as well as in text, make connections from their findings during their investigation.*

This interview response is reflective of DL45's entire interview transcript, which included references to key aspects of the NGSS, such as student talk and investigations, but did not mention any types of typical methods, such as teachers presenting information or a focus on the scientific method.

One final leader whose response in the survey did not match his interview response was DL06. His interview demonstrated that his beliefs align with the NGSS, however his survey response was coded for both NGSS instruction and typical instruction. However, the only non-NGSS code he received was for the use of the term “inquiry.” He wrote in the survey about effective instruction:

> *It is the addressing of phenomena and the quest to provide explanations of those phenomena based on evidence and inquiry resulting in the collection of data, analysis of the data. Model development for experimentation and prediction, research of existing knowledge and argument or defense of conclusions developed.*

In addition to the inquiry code, this response was coded as “investigating practices,” “sensemaking practices,” “critiquing practices” and “evidence.” However, in contrast to the research discussed previously about the term “inquiry,” DL06’s use of the term does appear to align with the NGSS. There were three other leaders who received the “inquiry” code as their only typical instruction code, but their responses were more vague than DL06, and absent the interview data it is impossible to ascertain whether they are using this term in ways that align with the NGSS similar to DL06.

This first theme indicates that district leaders believed that NGSS practice-based instruction is important for science students. However, almost half of the leaders also appeared to maintain their beliefs in more typical methods such as teachers presenting information to students, a belief that is likely not compatible with the goals of NGSS. Such beliefs about the NGSS and argumentation will likely have important implications for their leadership of teachers in their districts (NRC, 2015).

Theme 2: District leaders described multiple benefits of argumentation for students, including a focus on evidence, but almost never discussed the role of critique.

A second theme that emerged from the data focused on leaders' beliefs about the benefits of argumentation for students. The first factor included nine items about educational benefits of argumentation for students (Table 3.10), and as previously mentioned, 98% of the leaders' means for this factor were between 3.0 (agree) and 4.0 (strongly agree). This suggests that most leaders believed that argumentation offers important educational benefits for students. The second open-ended belief in the survey item also focused on this construct, and asked leaders to describe their beliefs about the benefits of argumentation for students (Figure 4.2). Leaders' open-ended responses demonstrated that leaders believed that there are a range of educational benefits for students. These included improved literacy skills (21 leaders), understandings of content (17 leaders), and critical thinking skills (13 leaders).

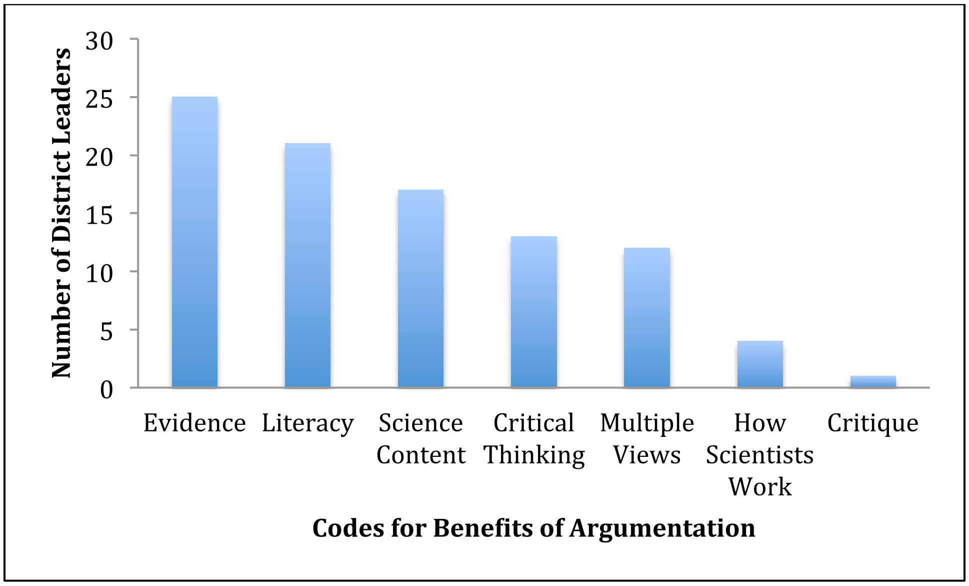


Figure 4.2
Frequencies of Codes for Open-Ended Survey Item: *What are the benefits of argumentation for students? (n = 53)*

For example, DL05 stated that argumentation can improve students' literacy skills, specifically their writing. He wrote in his survey, "Scientific argumentation can be linked to argumentative writing across curricula and help students develop logical arguments in support of ideas." DL26 asserted that argumentation helps make multiple views visible to students. He wrote in the survey "scientific argumentation challenges students to defend their beliefs and ideas while considering multiple perspectives." Similar to 22 (42%) of the district leaders, both DL05 and DL26 only received one code for their responses to this open-ended item.

However, more than half of the leaders' (31 leaders, 59%) responses were coded with more than one code, indicating that they believed argumentation has multiple benefits for students. For example, DL53 wrote "Scientific argumentation allows students to not only develop a better understanding of the science, but it also allows students to learn to problem solve, think logically, and communicate better. Regular use of scientific argumentation gives students the opportunity to practice these skills." This response was coded as "critical thinking," "literacy" and "content" for mentioning each of these as benefits of argumentation. DL28 focused on different benefits, and described his belief that argumentation helps students understand how scientists engage in their work and develop improved content knowledge:

> *It is an authentic scientific practice, and students need to participate in versions of authentic science practices to develop accurate conceptions of and concepts in science. Argumentation can motivate students by providing purpose for learning science content, which is a benefit because motivation is an essential element of learning. Argumentation can foster identify with science, as versions of*

> *argumentation are natural, and connecting science practice to natural activities can help students connect science to activities they identify with.*

This leader's response was coded as "how scientists work" and "content knowledge."

While leaders discussed a range of benefits for students engaged in argumentation, as shown in Figure 4.2, the most utilized code was "evidence" for mentions of argumentation benefitting students by engaging them in the use, analysis, or consideration of data and/or evidence. Twenty-five leaders (47%) discussed this benefit, with 20 of these leaders relating evidence to one or more of the other benefits. For example, DL36 wrote "Having students use evidence to justify their claims and explain their thinking, prompts students to think more deeply about why and how as opposed to the one right answer." This leader's belief about the benefit of evidence appeared linked to his belief about argumentation improving students' critical thinking skills. DL10 connected the use of evidence to supporting students in understanding the work of scientists. He wrote "This is the way that true science is done: collect data, present a reasonable argument. Defend the argument with data and present your evidence to a wide range of stakeholders." Similarly, DL43 believed the focus on evidence in argumentation supports students' conceptions of how scientists work, but she also connected evidence to improved literacy skills, specifically communication. She wrote, "Scientific argumentation provides students with an opportunity to communicate and refine their ideas. Also, it mirrors the practice of science, by having students communicate with one another and use evidence to support their claims."

Despite most leaders' beliefs in a range of benefits of argumentation for students, only one leader discussed critique in this way. DL18 discussed multiple benefits for students including improved content knowledge and exposure to multiple viewpoints, and he also mentioned evidence as a benefit. However, unlike any of the other leaders, DL18 connected evidence as a benefit to engaging students in critique. He wrote on the survey:

> *The process of argumentation offers an authentic context for students to learn and ultimately master both content and process skills in science. Student exchange of thinking creates room for nuanced understanding as opposed to surface level skill acquisition. Evaluation of peers and teacher provided evidence and viewpoints also develops critiquing skills in students that are difficult to isolate in other subject areas (or at least that will carry over to other subject areas).*

DL18 was the only leader who believed that argumentation enables students to develop important critiquing skills.

An analysis of the interview data supported the findings from the survey: leaders asserted a range of benefits for students engaged in argumentation, but rarely explicitly mentioned critique. For example, DL20 discussed literacy and content knowledge benefits in her survey response, and focused on literacy again in her interview. She said:

> *When students are engaged in kind of high-level academic discussion, they also, they feel more confident tackling a writing task after that, and inevitably will get some feedback from their peers as to the strength of their argument. They'll be sharing ideas with each other, they'll be bouncing ideas off each other. And then, I feel like that sets them up for success and then their writing responses are much more sophisticated after engaging in an argument.*

DL20 believed that argumentation can support students in becoming better writers because of the ways it engages students in sharing ideas. Similarly, DL38 focused on evidence as a benefit in his survey response and discussed this in his interview as well. However, in the interview he linked this benefit to students' life-long learning. He said:

> *And no matter where you go in the world or what occupation you're going to have, you're going to run into a problem; it's just, it's human nature that you're going to run into a problem. And if you, if you train your way of thinking you're trying to give yourself an advantage to get to the problem and try to find the root of the problem based on evidence and research.*

DL18 was the only leader to mention critique as a benefit in his survey, however he did not discuss critique in his interview. Instead, he described the benefits of argumentation as related to students using evidence beyond science. He said, "I mean, just fundamentally, the ability to support your claims with evidence, is foundational to every content area and essentially every career."

Despite the lack of focus on critique in their discussions of the benefits of argumentation, 13 leaders' responses to the first open-ended survey item (beliefs about effective science instruction) were coded as "critiquing practices" (Figure 3.1), indicating a mention of at least one of these two practices or key attributes of them. This would seem to suggest that leaders saw a role for critique in science instruction. Yet, of the 13 leaders who received this "critiquing practices" code, only one actually characterized argumentation as involving students in the critique of ideas. DL18 wrote that science learning "should include evaluation of evidence, justification (beyond simple explanation) of student thinking, and critique of opposing viewpoints." This was the same leader who stated in the survey that critique is an important benefit of science instruction. The remaining 12 leaders' responses were coded as "critiquing practices" for the mention one of the practices I categorized as a critiquing practice, scientific argumentation, but not for any discussion of critique specifically. This provides further evidence that while leaders appeared to believe that argumentation has multiple benefits for students especially related to evidence, they did not see critique as a key benefit.

Theme 3: District leaders believe “hands-on” science can involve students in the practices of science.

As previously mentioned, one item included in the first factor was not originally intended to reflect effective argumentation science instruction. The item referred to “hands-on” science, and was part of the group of items that were constructed to describe typical science instruction. However, thirty-one leaders (58%) “strongly agreed” and 20 leaders (38%) “agreed” with the Likert scale item that hands-on science is part of effective science instruction. One leader “strongly disagreed” and one leader “disagreed” with this statement. The ways in which the 51 district leaders who agreed and strongly agreed discussed their understandings of “hands-on” science in both their surveys responses and interviews indicated that it could have a range of meanings, some of which aligned with NGSS practice-based instruction.

In the survey, nine district leaders (17%) used the term “hands-on science” as part of their discussions of effective science instruction (Figure 4.3).

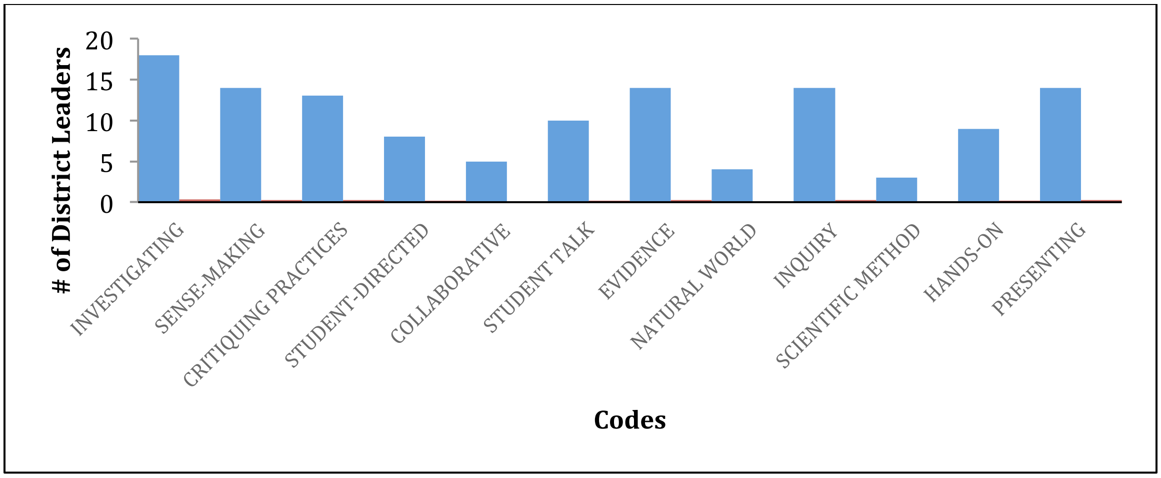


Figure 4.3: Frequencies of Codes for Open-Ended Survey Item: *What does good science instruction look like?* (n = 53)

Most of these leaders incorporated "hands-on" into their descriptions of student investigations. For example, DL50 wrote:

> *Good science instruction looks like activating prior knowledge, using hands-on investigation and direct interaction with phenomena to expose students to concepts/content in a constructivist way. Students use the tools of science and notebooking to record observations, collect data, and capture thinking, such as claims with evidence, reasoning, and reflections.*

This response demonstrated DL50's belief that "hands-on" means that students are participating in activities such as using tools and recording data, which are key components of the investigating practices in the NGSS. DL37 described "hands-on" science in similar ways. She wrote in the survey:

> *Good science instruction includes student-centered learning activities in which the students learn the targeted content through engaging in scientific practices and thinking (the scientific method is too linear of an approach). This includes*

> *hands-on laboratory type activities, problem-solving, project-based learning, and engineering tasks that drive the content learning for the students.*

For DL37, "hands-on" also referred to science practices that focus on gathering data.

The two leaders who used the term "hands-on" in their survey responses but did not refer to investigating used this term in less specific ways, typically referencing student activity in the classroom but not participation in experiments. For example, DL02 wrote that good science instruction is a "Balance between analyzing texts that support content acquisition, fostering student-to-student dialogue, and embedding a large hands-on/engineering component to engage learners and support inquiry." DL02 appeared to believe that hands-on experiences primarily are used to engage students, but not necessarily to gather data as DL50 or DL37 described.

One question in the interview asked leaders to define "hands-on" science, and these responses provided insight into leaders' beliefs about this term. Eight of the 10 leaders interviewed described "hands-on" science as being more than student activity in the classroom. For example, DL06 linked "hands-on" to both investigating and sensemaking practices:

> *It could be in a process of developing models, in a process of designing and carrying out experiments. It could be the process of analyzing data, and manipulating data through the use of calculators, spreadsheets, or whatever. It's not just kids doing something with their hands, it's beyond that.*

Similarly, DL17 said:

> *So, I think that hands-on experiences [are] led with a question and accesses the students' prior knowledge, but they are pursuing that question. Sometimes it's*

> *guided and sometimes, and depending on the age and experience level, sometimes it's more open. But they're, they're using tools and they're recording their data to try and answer that question.*

Both these quotes demonstrate that leaders could believe the term “hands-on” referred to more than student manipulation of materials or engagement in an activity in the classroom; instead, it could align with participation with investigating or even sensemaking practices. In his response, DL06 cited several of the investigating and sensemaking practices such as modeling and carrying out investigations and emphasized at the end of his response that “hands-on” is more than student activity. DL17 also linked “hands-on” to investigations, using the term to explain the ways that students collect data to answer a scientific question.

The two leaders who did not discuss “hands-on” as related to sensemaking or investigating science practices in their interviews were the two leaders who “disagreed” (DL28) and “strongly disagreed” (DL30) with the Likert scale item about hands-on science in the survey. In his interview, DL30 defined “hands-on” as referring to student activity but not science practices. He said, “Hands-on science experiences would be anything that would be an activity-based, lab-based, supply-based where they're not just sitting and reading a book or listening to someone speak at them. It should be something that they're actively engaged in doing.” This response along with his Likert-scale disagreement suggests that while DL30 valued students engaging with materials in the science classroom, he did not define “hands-on” as aligning with any science practices.

The leader who disagreed with the Likert-scale item on the survey was DL28. He explained in his interview that he did not believe this term aligned with practice-based instruction. He stated that he dislikes the term “hands-on” because he believes that it cannot fully capture what should occur in science classrooms. He said:

> *It might be that, so they are gathering evidence, they are arguing over, you know, how to gather that evidence, they are controlling the variables in service of that explanation or sense-making around a model, whatever it is. So, I'm a little hesitant to focus on, or even use hands-on to describe good science.*

Both DL28 and DL30 appeared to believe that the term “hands-on” does not refer to the NGSS science practices, which explains their lack of agreement with the Likert scale item about hands-on science. However, for most of the leaders in this study, “hands-on” cannot be assumed to only refer to typical science instruction, as some research suggests (e.g., Zembal-Saul, 2009). It can encompass practice-based instruction, especially as related to conducting investigations.

Theme 4: District leaders displayed a range of PCK for argumentation, with many demonstrating difficulty differentiating between evidence and reasoning and a limited understanding of the role of critique.

In addition to the belief items, the survey contained an assessment of PCK for argumentation. As described in chapter 3, this instrument utilized vignettes of classroom instruction to measure leaders’ PCK about structural and dialogical conceptions of scientific argumentation (Appendix A). Table 4.3 shows the scores broken down by conception and item type.

Table 4.3
Mean (SD) PCK Scores by Item Type and Conception (n=50)

	Multiple-Choice Items	**Open-Ended Items**	**Total**
Conception 1	4.30(1.23)*	1.64(1.47)**	5.94(2.06)
Conception 2	4.42(1.68)*	1.00(1.03)*	5.42(1.94)
Total	8.72(2.04)	2.64(1.71)	11.36(2.84)

*Out of 8 points   **Out of 12 points

Overall, leaders displayed a range of PCK for argumentation. The mean score was 11.36 out of 36 possible points. Scores ranged from 5 points to 18 points, with a mode of 12 points and a median of 12 points. For conception 1, which focused on the structural elements of an argument, specifically evidence and reasoning, the mean score was 5.94 out of 20 possible points, with the multiple-choice items having a mean of 4.30 out of 8 points and the open-ended items a mean of 1.64 out of 12 points (Table 4.3). Conception 2 focused on the dialogical aspects of argumentation, specifically student-to-student interactions and the use of competing claims in discourse. The mean was 5.42 points out of 16. The multiple-choice mean for conception 2 was 4.42 out of 8 points and the open-ended mean was 1.00 out of 8 points (Table 4.3). For both conceptions, leaders scored higher on the multiple choice items than the open-ended items, suggesting they found it easier to select an accurate student conception or appropriate instructional move rather than provide one and then describe their rationale for their response. In addition, research by Hill et al. (2004) suggests that test-taking skills and reasoning abilities can inflate multiple choice scores, one of the reasons that the inclusion of open-ended items is important in such measures. I will now discuss the data from the instrument related to each conception separately to discuss areas of greater strengths and challenges.

Conception 1: Structural Aspects of Argumentation. This first conception focused on leaders' understandings of high quality reasoning and evidence in an argument. Leaders' responses to the multiple-choice and open-ended items suggested that many leaders did not know what counts as high quality reasoning or evidence and may have confused evidence and reasoning. Eight multiple-choice items targeted this first conception. These items focused on leaders' abilities to assess the quality of students' evidence and reasoning and suggest appropriate instructional moves to improve students' use of evidence and reasoning in their arguments. One of the multiple-choice items for this conception is presented in Figure 4.4. In this item the teacher, Mr. Cedillo, was preparing to respond after a student stated her argument about how the surface on which a car travels affected its speed.

Ellen's argument:
The car on the ice will always go the fastest. I've been in a car driving on ice, and I know a car can skid because ice is the smoothest surface. My dad has a really big truck and it doesn't slide as far, so maybe next time we should try this experiment with larger cars.

Mr. Cedillo should respond by saying:

a) "Interesting point, Ellen. Does anyone have similar reasoning?"
b) "Great connection. Can anyone suggest data to support this?"[1]
c) "Nice argument. What additional evidence could Ellen add?"
d) "Well done. Does anyone else want to share their argument?"

[1] Correct Answer

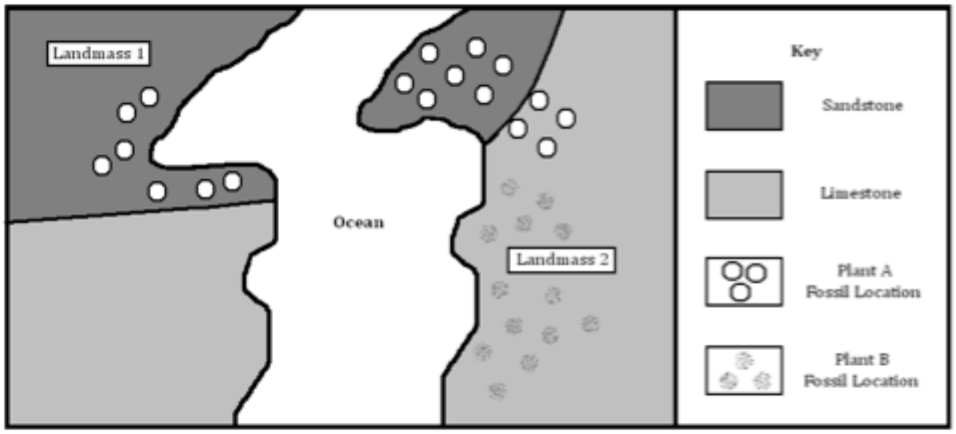
Figure 4.4: Sample Conception 1 Multiple-Choice Item: Evidence

As shown in Table 4.4, 20 leaders (26%) selected the correct answer, "b." This is the best choice because Ellen's argument did not contain any evidence, and an appropriate instructional move would be for Mr. Cedillo to ask Ellen's peers to recommend data for her to include. Selecting this choice suggested that leaders understood what counted as evidence because they could identify that Ellen did not include it in her argument. However, 11 leaders selected choice "a" ("Interesting point, Ellen. Does anyone have similar reasoning?”), even though Ellen did not have any scientific reasoning in her argument; 18 leaders selected choice “c” (“Nice argument. What additional evidence could Ellen add?"), despite the absence of evidence in Ellen’s argument; and one leader selected choice d (“Well done. Does anyone else want to share their argument”), a strategy that would not enable to Ellen to improve her argument (Table 4.4). The leaders’ choices suggest that most of them lacked an understanding of what counts as high quality evidence in science.

Table 4.4
Distribution of Leaders’ Choices: PCK Multiple-Choice Item Targeting Evidence

Choice	Number of Leaders
a. “Interesting point, Ellen. Does anyone have similar reasoning?”	11
b. "Great connection. Can anyone suggest data to support this?"	20
c. "Nice argument. What additional evidence could Ellen add?"	**18**
d. "Well done. Does anyone else want to share their argument?"	1

In addition to struggles with evidence, leaders also demonstrated challenges related to reasoning in scientific arguments. Reasoning is the link between the claim and evidence, and often utilizes a science concept to justify why the evidence supports the claim (McNeill & Krajcik, 2012). The multiple-choice item presented in Figure 4.5 targeted this construct. Leaders analyzed a student’s argument, which was based on a diagram of two landmasses that showed the locations of various types of fossils. The student constructed an argument about whether the landmasses were always in the same location or used to be in different locations.



Sofia's argument:
"I think these two landmasses were not always in the same location. They were probably connected without any ocean between them. I mean, look at the shapes of the masses. They look like they once fit into each other, like a puzzle. And remember how last week we read about Pangaea and how there used to be one big supercontinent on Earth?"

Sofia's argument:
a) Needs a more complete claim about the movement of the landmasses
b) Should include quantitative evidence so that it will be more convincing
c) Lacks an explanation of how the science concept supports her answer[1]
d) Contains an accurate rebuttal that is relevant to the landmass diagram

[1] Correct answer

Figure 4.5: Sample Conception 1 Multiple-Choice Item: Reasoning

The correct answer to this item is "c," a choice selected by fewer than a quarter of the leaders (19 leaders, 24.7%) (Table 4.5). Choice "c" is correct because Sofia's argument does not contain reasoning, which is an explanation of how the evidence supports the claim. However, 15 leaders chose "a" (Needs a more complete claim about the movement of the landmasses), despite the complete claim about the two landmasses were not always in the same location; 10 leaders selected "b" (Should include quantitative evidence so that it will be more convincing), yet there was no quantitative evidence available from the diagram (Appendix A); and six leaders selected "d" (Contains an accurate rebuttal that is relevant to the landmass diagram), however there was no rebuttal in the student's argument (Table 4.5). Selecting any of these choices suggests a challenge around understanding reasoning and the student's instructional needs related to reasoning.

Table 4.5
Distribution of Leaders' Choices: PCK Multiple-Choice Item Targeting Reasoning

Item Choices	Number of Leaders
a. Needs a more complete claim about the movement of the landmasses	15
b. Should include quantitative evidence so that it will be more convincing	10
c. Lacks an explanation of how the science concept supports her answer	**19**
d. Contains an accurate rebuttal that is relevant to the landmass diagram	6

One reason that leaders may have struggled with both evidence and reasoning in the multiple-choice items is that they confused these two constructs. In both the open-ended items for this conception, many leaders discussed evidence when asked for reasoning and vice versa. For example, the open-ended item focused on evidence utilized the same student argument in Figure 4.5 about the landmasses. Leaders were asked to identify the strengths and weaknesses of the evidence in the student's argument well as provide rationales for the stated strengths and weaknesses. Leaders could receive up to 2 points for each category, strengths, weaknesses, and rationale, for a total of 6 possible points. Table 4.7 shows the breakdown of scores for each of the three coding categories as well as the distribution of total scores for this item.

Table 4.7
Distribution of Scores for Conception 1 PCK Open-Ended Item: Strengths and Weaknesses of Evidence

	Number of Leaders			
	Strengths Code	**Weaknesses Code**	**Rationale Code**	**Total Score**
0	35	25	48	22
1	11	9	2	5
2	1	16	0	18
3	N/A	N/A	N/A	5
4	N/A	N/A	N/A	0
5	N/A	N/A	N/A	0
6	N/A	N/A	N/A	0

Twenty-two leaders' responses received 0 points, while 5 leaders' responses were coded as 1 point, 18 leaders as 2 points and 5 leaders as 3 points. While leaders struggled to identify strengths and weaknesses of the student's evidence, many responses also suggested confusion between evidence and reasoning. For example, DL34 received points for accurately discussing the weakness in the student's response. However, she described the strengths related to science concepts, not evidence:

> *A strength is that she uses her knowledge of how land masses move to build her argument. A weakness is that she doesn't use all of the available evidence to*

> *support her claim. She could have also talked about the fossil locations and whether there was overlap.*

DL34 accurately identified that the student did not utilize all the possible evidence about fossils in her argument. However, she also discussed that the student did not use "knowledge of how land masses move" in her argument. While this is important as part of a scientific argument, such science concepts are reasoning, not evidence.

Similar to 22 other leaders, DL47 did not receive any points. She wrote "a strength is that Sofia is using prior knowledge as evidence by bringing in Pangaea. Weakness include no mention of the types of landmasses." DL47's reference to prior knowledge as evidence indicated a lack of understanding of what counts as high quality evidence in science (i.e. data such as observations or measurements). Information about the ancient supercontinent of Pangaea can contribute to the reasoning, but is not scientific evidence.

The responses to the two open-ended items as well as the scores from the multiple-choice questions related to this first conception indicated that while leaders appeared to understand that arguments must be justified with evidence and reasoning, many struggled to differentiate between evidence and reasoning or identify high-quality examples of each. Therefore, it is likely that such leaders would be challenged to design learning opportunities to support teachers in learning about reasoning or evidence in argumentation, or how to integrate these components of argumentation into their classroom instruction.

Conception 2: Dialogical Aspects of Argumentation. This second conception focused on leaders' understandings of student-to-student interactions in argumentation and the use of competing claims in such experiences. Crucial to both aspects of this dialogical conception is the concept of critique; students are expected to critique both multiple claims and their peers' arguments.

As with the structural conception, eight multiple-choice items targeted this dialogical conception. These items focused on leaders' abilities to assess the quality of student interactions and consideration of multiple claims, and suggest appropriate instructional moves to engage students in dialogical argumentation. One item that focused on leaders' understandings of the role of competing claims is shown in Figure 4.6. This question asked the leader to identify the best instructional move for the teacher, Ms. Alves, who wanted students to critique each other's arguments.

After writing their arguments, Ms. Alves groups students with opposing claims together and asks them to provide each other with constructive feedback. Ms. Alves notices that students are not critiquing each other's arguments.

Which of the following strategies would help her students do so?

a) Have each student use a rubric to evaluate their own scientific argument
b) Model what counts as appropriate high-quality evidence for the strongest claim
c) Do a mini-lesson to demonstrate how to write a convincing scientific argument
d) Show the students a video of a scientist questioning another scientist's claim[1]

[1] Correct answer

Figure 4.6: Sample Conception 2 Multiple-Choice Item: Competing Claims

The correct answer is "d" (Show the students a video of a scientist questioning another scientist's claim). Such an instructional move could model for students the ways that scientists engage in critique and provide students with both the motivation and strategies to do so in the classroom. However, as shown in in Table 4.8, only 19 leaders (38%) selected this answer.

Table 4.8

Distribution of Leaders' Choices: PCK Multiple-Choice Item Targeting Competing Claims

Choice	Number of Leaders
a. Have each student use a rubric to evaluate their own scientific argument	13
b. Model what counts as appropriate high-quality evidence for the strongest claim	13
c. Do a mini-lesson to demonstrate how to write a convincing scientific argument	5
d. Show the students a video of a scientist questioning another scientist's claim	**19**

Of the remaining 31 leaders, 13 selected "a" (Have each student use a rubric to evaluate their own scientific argument); 13 selected "b" (Model what counts as appropriate high-quality evidence for the strongest claim); and 9 selected "c" (Do a mini-lesson to demonstrate how to write a convincing scientific argument) (Table 4.8). However, none of these choices would help students engage in critique. For example, while choice "c" could support students in being more persuasive in their writing, such a mini-lesson would not likely help students to critique each other's arguments. This suggests that leaders either did not understand the role of critique in argumentation or lacked sufficient knowledge of how to engage students in it.

This finding is further supported by leaders' responses to the open-ended items for this conception. In these items, leaders struggled to provide appropriate strategies for engaging students in peer-to-peer argumentation and rarely mentioned critique. In one vignette, a teacher provides students with a text about scientists' competing claims about how to classify a new organism that exhibits characteristics of both plants and animals. The teacher encourages students to debate whether this organism should be classified as a plant or an animal. The open-ended item then asked leaders to describe the benefits and drawbacks to a teacher's strategy of having students debate a topic with multiple claims. Leaders received 0 points for describing inappropriate benefits, 1 point for one appropriate benefit or a combination of appropriate and inappropriate benefits, and 2 points for two appropriate benefits. Leaders also received 0 points for describing inappropriate drawbacks, 1 point for either not discussing drawbacks or providing a vague drawback, and 2 points for stating there are no drawbacks. Table 4.9 shows the breakdown of scores for each of the coding categories.

Table 4.9
Distribution of Scores for Conception 2 PCK Open-Ended Item: Benefits and Drawbacks of Competing Claims

	Number of Leaders		
	Benefits Code	**Drawbacks Code**	**Total Score**
0 points	33	32	22
1 point	16	14	20
2 points	1	3	6
3 points	N/A	N/A	2
4 points	N/A	N/A	0

Twenty-two leaders received 0 points for their responses, with 20 leaders receiving 1 point, six leaders receiving 2 points and two leaders receiving 2 points (Table 4.10). Only 17 leaders provided one or more appropriate benefits and only three leaders stated that there are no drawbacks to engaging students in argumentation about competing claims. One leader who stated an accurate benefit was DL41. She said that engaging students in debating multiple claims “Allows for students to express their ideas with peers, hearing counter arguments, or supporting ones.” Likewise, DL31 wrote, “Benefits is it shows multiple perspectives/counter claims. Permits students to see how things can be in the scientific world.” The 17 leaders who earned points for their responses similarly discussed exposing students to multiple perspectives about science or that scientists often grapple with multiple claims. However, only one of these leaders mentioned that utilizing multiple claims could provide students with opportunities to engage in critique:

> *The benefits of this approach significantly outweigh the drawbacks. First, students must UNDERSTAND various claims in order to compare them. Then they must critique the validity of contrasting arguments. This requires them to connect claims to evidence through reasoning. Ultimately, having to take a position on one of two (or more) arguments requires students to formulate new, evidence-based arguments. That's science!*

DL21 received one point for the mention of critique as a benefit; he accurately described the importance of students critiquing “contrasting arguments.”

While 17 leaders earned points for discussing accurate benefits (Table 4.10), more than half the leaders (29 leaders, 58%) mentioned inappropriate drawbacks to students engaging with multiple claims, such as that it takes too much time and that some types of students are less capable of complex learning. However, the most frequently mentioned inappropriate drawback (17 leaders, 34%) was that students would develop misconceptions about science concepts. For example, DL09 stated that the teacher must "make sure that they are getting correct scientific information and not cementing incorrect information" and DL11 wrote "students' naive science ideas can become deep misconceptions." However, research indicates that student learning of content can be improved by argumentation, not diminished (e.g., Venville & Dawson, 2012). Therefore, such beliefs could mean that leaders would be reluctant to encourage teachers to utilize such strategies in their instruction.

The second open-ended question about student-to-student interactions focused on strategies that would support students in engaging in oral argumentation in the classroom. This question asked leaders to provide two such strategies and to explain their rationales for these strategies. As shown in Table 4.10, 40 leaders received 0 points, with most of the points for the remaining 10 leaders coming from accurate discussions of strategies to engage students in oral argumentation.

Table 4.10
Distribution of Scores for Conception 2 PCK Open-Ended Item: Strategies for Oral Argumentation

	Number of Leaders		
	Strategies Code	**Rationale Code**	**Total Score**
0 points	41	49	40
1 point	7	1	8
2 points	2	0	2
3 points	N/A	N/A	0
4 points	N/A	N/A	0

DL04 was one of the few leaders who provided two appropriate strategies. She wrote, “Open ended questioning allowing students to build upon each other. Asking ‘why?’ and ‘Can you build on that?’ Also, having students repeat what another has said. ‘Can you paraphrase what Gustavo said? How would you argue that?’” Both these strategies could support students in talking to each other in argumentation discussions. DL13 provided one appropriate strategy and one inappropriate strategy. She wrote on her survey:

> *Student to student talk as the strategy and activities such as Socratic seminar or give one get one. This gives students practice at speaking their thoughts and requires them to use evidence to do so. Critical reading strategies such as marking the text, pausing to connect, are essential for students to be able to identify their supporting evidence.*

DL13’s first strategy of using a Socratic seminar could help students participate in oral argumentation. However, critical reading strategies focused on evidence pertain to the structural aspects of argumentation and are unlikely to support students to engage in classroom discourse. DL13’s second strategy represented a common response for the leaders who received few or no points for this open-ended item: they focused on the structure of an argument, especially the importance of utilizing evidence, instead of dialogical interactions. For example, DL 24 wrote, “Students should be encouraged to support their claims using evidence. This provides “substance” to their argument. Teachers should emphasize the link among claims, evidence and reasoning.” This response is an accurate characterization of argumentation, but it focused on the structure of an argument, not students engaging in dialogic discourse.

The analysis of leaders' responses to the PCK instrument indicated several challenges for leaders' PCK for argumentation. Specifically, leaders struggled to identify high-quality evidence and reasoning and may have confused these constructs. In addition, leaders were challenged to provide appropriate instructional strategies to engage students in dialogical interactions and most did not mention critique as an important component of such discourse. These findings suggest that districts should consider ways to support their leaders in developing more substantial PCK for argumentation and the other science practices before tasking these leaders with designing education opportunities for teachers in their districts.

Theme 5: District leaders' beliefs about the level of alignment of current instruction with argumentation appeared to be impacted more by beliefs about local conditions than their PCK or beliefs about argumentation.

As I discussed in chapter 3, my original hypothesis was that leaders who believed that instruction in their districts aligns with the goals of argumentation would have lower PCK for argumentation and would be more likely to believe typical instructional strategies are effective. In essence, if leaders think argumentation is happening, they probably don't know what argumentation really is. This view was influenced by research that suggests that since NGSS is a new policy, it is unlikely to be fully implemented in most districts (e.g., Krajcik et al., 2014; NRC, 2015). Therefore, if leaders believed there is substantial alignment, these views are inaccurate. However, as I will discuss, my findings call this assertion and my original hypothesis into question. Instead, leaders' responses indicated that their beliefs about specific conditions in their districts may have been more influential on their beliefs about alignment.

The final Likert scale question in the survey asked leaders to “strongly disagree,” “disagree,” “agree,” or “strongly agree” with the statement: *Overall, the science instruction in my district is closely aligned with the goals of scientific argumentation*. The mean for this item was 2.3, close to “disagree” (2.0) with a mode of 2.0, “disagree.” Five leaders selected “strongly disagree,” 28 leaders selected “disagree,” 17 leaders selected “agree,” and three leaders selected “strongly agree” (Table 4.11). Therefore, almost two-thirds of the leaders (33 leaders, 62%) did not believe that instruction in their districts aligned with the goals of argumentation.

Table 4.11
Factor and PCK Means by Level of Agreement that District Instruction Aligns with the Goals of Argumentation (n=53)

Level of Agreement	**Number of Leaders**	**Factor 1 – NGSS-Aligned Mean**	**Factor 2 – Typical Science Mean**	**PCK Mean[1]**
Strongly Disagree	5	2.95(1.10)	2.63(0.74)	9.0(1.41)
Disagree	28	3.56(0.29)	2.26(0.52)	12.1(2.84)
Agree	17	3.51(0.28)	2.18(0.31)	10.44(2.28)
Strongly Agree	3	3.75(0.28)	1.57(0.29)	11.0(4.58)

[1] n=50 for the PCK instrument as 3 leaders did not complete this part of the survey

I ran three ANOVAs to determine whether the means for the two belief factors (Table 4.2) and total PCK scores were statistically significantly different for leaders who strongly disagreed, disagreed, agreed, or strongly agreed that the instruction in their districts aligned with the goals of scientific argumentation. As described in Theme 1, Factor 1 included Likert scale items focused on NGSS and argumentation-aligned instruction and benefits, and Factor 2 included items describing typical instruction (Table 4.2).

I found no significant differences for PCK scores between these groups, however I did find a significant difference for Factor 1 *F* (3,49) = 3.46, $p<0.05$, and for Factor 2 *F* (3,49) = 3.13, $p<0.05$. I ran post-hoc Tukey tests to determine where the significant differences occurred for each factor. For Factor 1, beliefs about NGSS-aligned instruction and argumentation benefits, there was a statistically significant difference between the means for leaders who strongly disagreed (M=2.95, SD=1.1) that the instruction in their districts aligned with the goals of scientific argumentation and leaders who disagreed (M=3.55, SD=0.29) with this statement. There was also a statistically significant difference between the mean for leaders who strongly disagreed (M=2.95, SD=1.1) and agreed (M=3.51, SD=0.28) that the instruction in their districts aligned with the goals of argumentation. However, it appears that one leader's mean for Factor 1 may have lowered the means for leaders who strongly disagreed. DL30 had a mean of 1.05 for this factor, while the remaining four leaders in this group had means around 3.0. In addition, these findings do not suggest any important differences between these groups, as despite a statistically significant difference, all of the means were still around "agree" (3.0) or "strongly agree" (4.0). This indicates an overall agreement with the instruction described in Factor 1 and confirms one of the findings described in Theme 1: leaders appeared to value instruction aligned with the NGSS and argumentation.

For Factor 2, beliefs about typical science instruction, the post-hoc Tukey test indicated a statistically significant difference between the mean for leaders who strongly disagreed (M=2.63, SD=0.74) and leaders who strongly agreed (M=1.57, SD=0.29) that the instruction in their districts aligned with the goals of argumentation. Leaders who "strongly agreed" that there was alignment between the goals of argumentation in their districts “disagreed” (2.0) with the typical instructional strategies described in the Likert scale items included in Factor 2. Leaders who “strongly disagreed” that there is alignment, were closer to “agree” (3.0) with the typical methods. This is the opposite of what I expected and what research suggests (e.g., Krajcik et al., 2014). However, these were both small groups (See Table 4.12) and for 45 of the 53 leaders, there was not a significant difference in their Factor 2 beliefs.

One possible reason for these statistical findings is that most leaders believed that teachers in their districts needed to shift their instruction away from typical methods. In the final open-ended belief item, leaders were asked to describe the ways that instruction in their districts aligns and does not align with the goals of argumentation. Thirty-one of the fifty leaders who answered this item discussed the importance of supporting teachers to shift away from typical instructional methods in their responses. Such responses were given a “typical instruction” code, indicating that they discussed a need to move away from typical instructional methods or described such pedagogy as not aligning with argumentation. For example, DL35 wrote that there is “[t]oo much focus on content and confirmation of already known ideas.” DL19 wrote, “Some teachers are more traditional in the classroom. They introduce a topic through powerpoint notes, they have students practice the skill and then do a lab to reinforce the skill.” DL17 wrote that in her district “Some schools are still introducing content (concepts & vocabulary) in advance of hands-on and in advance of argumentation.”

All the interviewed leaders discussed typical instruction in similar ways, such as DL40 who said, “I think that we need to change from the just providing the information to kids." DL17 explained his plans for professional development to support teachers in changing their instruction:

> *"I think teachers need more training. They need to watch more teachers do argumentation, they need to watch more videos, they need more time to analyze the teacher moves in the video, or look at transcripts. And....and they need to look at student writing around claim and evidence and reasoning, and use rubrics and evaluate that writing and say, 'Ok. This would be my next step,' or 'This would be my next mini lesson.'"*

Such leaders appeared to understand that argumentation instruction is substantially different than typical science teaching. However, some of these types of typical instruction that leaders described as conflicting with argumentation instruction are the same that some did not fully disagree with in Factor 2, such as teachers presenting instruction. As such, while most district leaders believed that typical instruction does not align with argumentation or the NGSS, some may simultaneously be struggling to let go of their beliefs about the effectiveness of such pedagogy.

However, despite many leaders asserting that teachers need to shift away from typical strategies, few leaders accurately described argumentation in their responses. In addition to the "typical instruction" code, leaders' responses were coded based on the accuracy of the descriptions of argumentation to address my original prediction (Figure 4.7). Specifically, I expected to see misunderstandings or inaccurate beliefs of argumentation for leaders who believed there is alignment in their districts. However, most leaders provided vague descriptions of argumentation in their responses, making it difficult to discern any relationship between argumentation understanding and alignment beliefs. Only eight leaders' responses were coded as containing at least one accurate feature of argumentation. For example, DL02 discussed students engaging in debate, and DL24 who wrote "Teachers are beginning to teach students how to reason scientifically by supporting their claims with evidence. Students also engage in debates pertaining to controversial topics (i.e. nuclear energy, genetic technology)." DL24 accurately described several key features of argumentation in the classroom, including claims supported by evidence and engaging students in debate. Eleven leaders provided inaccurate descriptions of argumentation, such as DL26 who wrote that he sees students engaging in argumentation because "Students are asked to challenge their beliefs and find ways to defend the authenticity of these beliefs (i.e. gravity acts down, mass is conserved in a chemical reaction)." While instruction should help students develop more accurate understandings of science concepts, this is not an accurate description of the practice of argumentation. Argumentation should focus on students challenging each other's claims that are supported by evidence, not their beliefs about various topics.

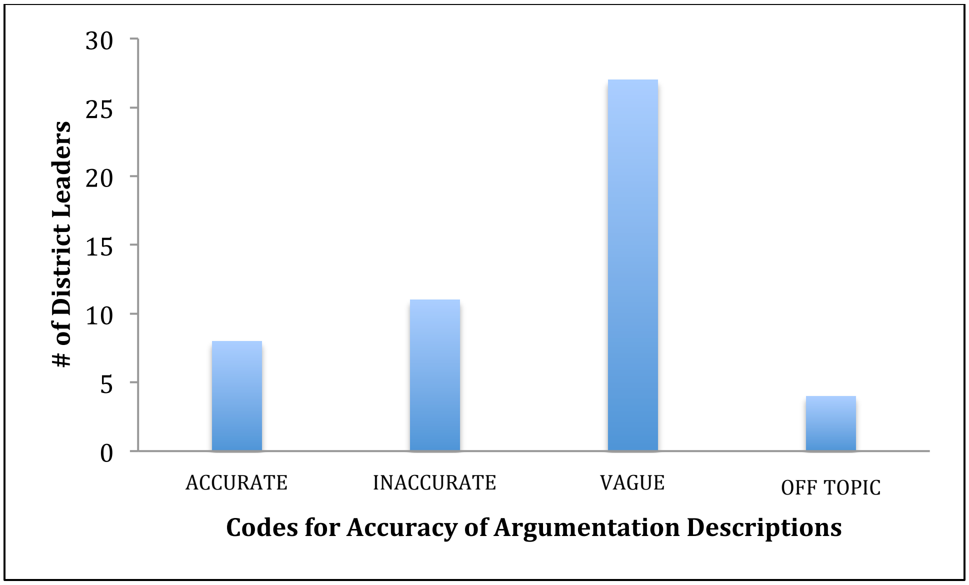


Figure 4.7: Distributions of Accuracy Codes for Open-Ended Survey Items: *In what ways does the instruction in your district align with the goals of argumentation? In what ways does the instruction in your district not align with the goals of argumentation? (n =53)*

Twenty-seven leaders' responses to these open-ended items received the "vague" code, such as DL47. She wrote "Teachers in my district are only beginning to align instruction with the goals of scientific argumentation." Similarly, DL45 wrote "Some teachers still use it as an isolated practice instead of a culture in their classroom. As part of the culture in the classroom it would become routine for our students." While both these responses did not contain sufficient detail to assess the accuracy of their knowledge of argumentation, they did suggest that additional factors impacted leaders' alignment beliefs.

Further analysis of the open-ended responses and interview data suggested that leaders' beliefs about specific conditions in their districts may have played a role in how they viewed alignment. Eighteen of the surveyed leaders and all 10 of the interviewed leaders discussed their beliefs about various circumstances in their districts, such the timeline for NGSS adoption, the nature of science teaching at different levels, time constraints, and budgetary concerns that appear to have influenced their alignment beliefs. For example, DL20 "strongly agreed" on the survey that there is alignment between classroom instruction and the goals of argumentation in her district. In her interview she explained that her district was an early adopter of the NGSS and the teachers have been learning about science practices, in particular scientific argumentation, for some time. She also discussed that the professional development in her district last year focused on argumentation across the disciplines. As such, DL20's beliefs about teachers' experiences with argumentation appear to have influenced her belief about strong alignment. Conversely, DL04 "disagreed" that there is alignment between argumentation goals and current science instruction in her district. However, in her interview, she described elementary and middle school teachers as having much success integrating argumentation in their instruction, but "high school is a little bit, to me, that's the where the difficulties lie, that's my biggest challenge because they are so content-specific, you know?" DL04 disagreed about alignment because of her beliefs about science instruction at different levels. However, both these leaders, DL20 and DL04, earned a total of 10 points on the PCK instrument, and had comparable beliefs for each of the factors. DL20 had a mean of 3.80, close to "strongly agree" for Factor 1, and a mean of 1.86 for Factor 2, close to "disagree." Similarly, DL04 had a mean of 3.60 for Factor 1, and a mean of 2.14 for Factor 2. Therefore, these data suggest that leaders' beliefs about factors specific to their districts contributed to their alignment beliefs more than their argumentation beliefs or PCK for argumentation.

This final theme indicates that leaders' beliefs and knowledge of argumentation may not be related to their beliefs about alignment of instruction with the goals of argumentation in their districts. It appears that beliefs about specific conditions in leaders' districts may be more influential. This finding highlights the importance of considering the context in which leaders work in the design of professional learning and in the implementation of the NGSS.

Summary

The results for the survey and interviews indicate substantial "buy-in" for the NGSS, especially the science practice of argumentation. However, the first theme presents a complex picture of the beliefs of leaders about the NGSS and argumentation, as almost all the leaders agreed with instructional strategies and benefits of the NGSS and argumentation, but almost half of the leaders appeared unwilling to "let go" of more typical strategies. The second theme provided a closer look at leaders' beliefs about the benefits of argumentation for students, and suggested that while many leaders see various benefits to student engagement in argumentation, especially related to evidence, few discussed critique in the same way. The third theme focused on an often-used term in science education, "hands-on," and indicated that many leaders may be expanding on the definition of this term to include some science practices.

Despite the findings from the first three themes, the results described in the fourth theme suggest that leaders struggled with several important aspects of PCK for argumentation. These areas include identifying and developing instructional strategies around high quality evidence and reasoning, and being able to support students in dialogical interactions in which they critique competing claims.

The final theme suggests that contextual factors may contribute to leaders' beliefs about the alignment of instruction in their districts with argumentation, rather than argumentation beliefs or PCK for argumentation. Most leaders believed that teachers will need to shift their instruction to accomplish the goals of argumentation. However, given the challenges leaders displayed with PCK for argumentation, leaders may be challenged to support teachers in such a shift. This final theme along with the four previous themes indicates several important areas for professional development for leaders, as well as implications for district policy to support the implementation of the NGSS.

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

This dissertation focuses on the beliefs and pedagogical content knowledge (PCK) of district science leaders about the NGSS science practice of argumentation. As of March 2016, 17 states and the District of Columbia had adopted the NGSS, and other states, such as Massachusetts, adapted the NGSS to create their own new state science standards. Teachers across the country will need to shift their science instruction to meet the demands of NGSS, especially regarding the practice of argumentation (NRC, 2015; National Academies of Sciences, Engineering & Medicine, 2015; Osborne, 2014). Argumentation demands that students engage in debating, critiquing, and questioning each other's claims and evidence (Krajcik et al., 2014), instead of more typical methods of science teaching that involve teachers and textbooks transmitting information to students (Osborne, 2014; NRC, 2012; Berland & Reiser, 2009). While typical science instruction tends to portray science as a body of facts, the NGSS aim to engage students in the practices of science to collectively build knowledge about the natural world (Pruitt, 2014).

The NGSS may be the policy in several states, but its adoption is not enough to assure a change in classroom instruction (Hill, 2001; Darling-Hammond, 2004; Spillane, 2004; Fullan, 2007). As Elmore & Burney (1997) explained in their report on educational reforms in New York City's District #2, "Policies, by themselves, don't impart new knowledge; they create the occasion for educators to seek new knowledge and turn that knowledge into new practice" (p. 2). Therefore, for the NGSS to be a successful educational reform, teachers will need substantial support to transform their instruction to meet the goals of these new standards (Reiser, 2013). Such support will likely come in large part from professional development designed and delivered by science leaders at the district level (Achieve, 2013; National Academies of Sciences, Engineering & Medicine, 2015). This professional development will hopefully enable teachers to change their beliefs about science education and learn new instructional techniques that engage students in the types of knowledge construction and critique prioritized by the NGSS (Reiser, 2013; National Academies of Sciences, Engineering & Medicine, 2015). However, while recent publications address the design of teacher education (e.g., Reiser, 2013), similar to most research about professional development, little attention is paid to those designing and leading teacher education opportunities (Luft & Hewson, 2014; Fullan, 2007). This is concerning given the ways that leaders' conceptions of educational reforms have been shown to influence how teachers come to understand them and enact them in their classrooms (Spillane, 2004; Coburn, 2005; Coburn, 2006).

The success of the NGSS will initially hinge on leaders and teachers developing a shared vision of science education that is consistent with the goals of the standards (NRC, 2015). The findings from this dissertation suggest that district leaders valued argumentation; however, many did not conceptualize the goals of the NGSS and argumentation in ways that reflected this policy. All the district leaders held positive beliefs about the NGSS science practices, especially argumentation, and believed that instructional strategies aligned with the practices were elements of effective science instruction. Many of these leaders incorporated the NGSS science practices into their descriptions of effective science instruction, and some appeared to expand their definitions of "hands-on" science to include these science practices. In addition, more than half the leaders recognized that teachers in their districts must change how they teach to meet these goals. However, the data also suggested that many leaders' visions of the NGSS and argumentation differed from the goals of the NGSS. Specifically, almost half of the district leaders in this study did not believe that strategies associated with typical science teaching approaches were ineffective, and almost all did not see critique as a key component of argumentation. In addition, leaders demonstrated a range of understandings of how to teach argumentation in the classroom (i.e., PCK), with most leaders struggling with both structural and dialogical aspects of argumentation, which will impact their leadership of teachers (Stein & Nelson, 2003). All of the district leaders reported being responsible for designing professional development for teachers in their districts, and therefore, their beliefs and understandings of argumentation can present a challenge to the successful implementation of the NGSS in their school districts.

In this chapter I situate these findings in the larger body of literature and discuss in more detail their implications. Specifically, I examine two of the key differences between leaders' beliefs about the NGSS and argumentation compared to the vision described in policy documents (NRC, 2012; NRC, 2015; NGSS Lead States, 2013). I then utilize the sensemaking theoretical framework (Weick, 1995; Spillane, 2004) that I described in Chapter 2 to suggest reasons for such differences. I also address the areas in which leaders struggled with the PCK instrument and discuss the design and role of professional development to support district leaders in developing beliefs and knowledge that more closely reflect the goals of the NGSS. I close the chapter with a discussion of the limitations of this study and suggested areas of future research.

District Leaders' Visions of the NGSS

The NGSS set forth ambitious goals for science teaching and learning in the United States. While it is not a curriculum or prescription for science instruction, for science teaching and learning to achieve the goals of the NGSS everyone, especially leaders, must "understand the vision of the NGSS and actively work to support it" (NRC, 2015, p. 87). The findings from this dissertation indicated broad acceptance of and enthusiasm for argumentation and the NGSS, a necessary component for the initiation of educational change (Fullan, 2007). Not one leader discussed resistance to the NGSS or the belief that the NGSS was just a passing fad in education. Instead, the leaders described high quality science instruction as including the NGSS science practices. In addition, leaders also incorporated the science practices into their descriptions of "hands-on" science. For example, most of the leaders who participated in the interviews defined "hands-on" science as relating to investigating and/or sensemaking practices. Leaders also discussed various benefits to students engaged in argumentation, such as improved literacy and critical thinking skills. However, the data also suggested two key areas in which leaders' visions differed from the goals embodied in the NGSS: (1) some leaders' conceptions about the compatibility of typical instructional methods with the NGSS; and (2) most leaders' beliefs about the role of critique in argumentation.

Beliefs about typical science instruction. The success of the NGSS hinges on a substantial change in science teaching and learning (NRC, 2015; National Academies of Sciences, Engineering & Medicine, 2015; Krajcik et al., 2014; Bybee, 2014). However, despite most leaders asserting that teachers must change their instruction to align with the NGSS, almost half of the leaders in this study described typical strategies as part of effective science instruction (Figure 4.1). These typical strategies included teacher-controlled methods, such as teachers presenting information to students, and outdated views of science, such as an emphasis on the scientific method. Previous research on educational reforms has documented similar findings, specifically that teachers can value aspects of reform-based instruction while still believing in the benefits of typical strategies (Banilower et al., 2013).

However, typical instructional strategies are not always compatible with the NGSS, because such methods most often do not engage students in the social construction of knowledge (NRC, 2012). Typical strategies position the teacher and the textbook as the source of knowledge (Berland & Reiser, 2009; Newton et al., 1999) and focus on students learning science as a set of facts (Alozie et al., 2010; DeBoer, 2000). Students typically do not work together to construct new understandings about the natural world in ways similar to scientists (Reiser, 2013). Passmore and Svoboda (2012) argue that “too often in school science this important feature of inquiry is done in advance for students, and they are not allowed to see the difficulty and intellectual challenge inherent in figuring out just how to go about answering a question.” The NGSS aim to shift this paradigm so that students work together to “figure out” aspects of the natural world utilizing the practices of science (Reiser, 2013).

The emphasis in the NGSS on students using the practices of scientists to socially construct knowledge (Krajcik et al., 2014) necessitates that students engage in the discourses, critical thinking, and explorations of scientists (NRC, 2012). To accomplish the goals of the NGSS, leaders and teachers will need to let go of typical instructional methods as the driver of science lessons. Instead, leaders need to learn strategies that reflect this new and fundamentally transformed vision of what it means for students to learn science (Reiser, 2013). For example, instead of directing student discussions, teachers must step back and let students talk directly to each other. My findings suggest that almost half of the leaders who participated in this study may not have a vision of the NGSS that includes moving away from such strategies.

Beliefs about critique. A second area where leaders' visions differed with the goals of the NGSS is about critique. Few leaders in this study mentioned critique when discussing their beliefs about the NGSS or argumentation, and only one leader believed that critique was a benefit of argumentation for students. This was not surprising, as critique requires a different epistemological view of science, one that contrasts with the dominant perspective in science classrooms and society in general (Osborne, 2014; Henderson et al., 2015). While most individuals view science as an established body of knowledge, it is actually a dynamic process in which developing theories are debated and revised as new evidence is uncovered (Osborne, 2014). The NGSS emphasize the need for students to develop accurate understandings of the epistemology of science, and therefore, students must engage in critique in the classroom (Ford, 2015). While science educational reforms sometimes overemphasize knowledge building (Henderson et al., 2015), Ford (2008) asserts that knowledge building and critique are synergistic, because one can only effectively build knowledge by critiquing developing knowledge.

Henderson et al. (2015) found five benefits to engaging students in critique in the science classroom: the development of more accurate views of the nature of science, improved understandings of the epistemology of science, improved scientific literacy skills, increased meaningfulness of classroom learning for students, and increased student motivation. Some of these are the same that leaders in this dissertation believed are benefits for students engaged in argumentation. For example, on the survey, 21 leaders' open-ended responses about the benefits of argumentation were coded as "literacy" (Figure 4.2), indicating that they believed that students' reading, writing, and communication skills can be improved through participation in scientific argumentation. However, none of these leaders discussed these literacy benefits as related to critique. These leaders may not understand that for the literacy benefits to be realized, students must not only construct, but also critique, oral and written arguments (Henderson et al., 2015). Similarly, 17 leaders discussed improved content knowledge as a benefit to student engagement in argumentation. However, students' understanding of content is improved in part as a result of critiquing peers' developing knowledge (Henderson et al., 2015). It is reassuring that leaders see multiple benefits to students engaging in argumentation, but for students to truly benefit in these ways necessitates that they critique conflicting arguments in ways similar to scientists (Henderson et al., 2015). This is a substantial challenge for teachers, as it requires a shift away from teachers acting as "knowledge intermediaries between science and its students" (Henderson et al., 2015, p. 1672), towards students talking with each other as they critique ideas to construct their own understandings of phenomena.

Shared visions and policy. My findings in this dissertation indicate that leaders' visions of the NGSS misaligned with policy documents (e.g., NGSS Lead States, 2013; NRC, 2012) in two key ways: (1) some leaders' visions included typical science instruction methods as being compatible with the NGSS; and (2) almost all leaders' visions did not include critique. Leaders' visions of the NGSS must align with its goals for the policy to be successful (NRC, 2015). Research about New York City District #2's literacy reforms, for example, demonstrate that leaders' shared visions of educational reforms were essential for the design of professional development that successfully impacted teachers' instruction (Elmore & Burney, 1997; Stein & D'Amico, 2002). In this district, the superintendent made a substantial commitment of resources, including time, money, and people, to improve the teaching and learning of reading (Elmore & Burney, 1997). The district adopted a research-based reading program that valued different approaches to reading instruction than were occurring in most district classrooms. Similar to the NGSS, this educational reform necessitated substantial changes in teachers' beliefs, in this case about reading instruction, and the development of new instructional methods (Stein, Hubbard, & Meehan, 2004). However, before any professional development with teachers began, the district leaders worked to develop a shared understanding of how students learn to read and the instructional implications of such a shift (Stein & D'Amico, 2002). This common vision then guided leaders' decisions about professional development and other types of supports for teachers that helped teachers effectively change their instruction (Elmore & Burney, 1997).

However, when leaders from New York attempted to implement this same reform in San Diego they did not experience the same success. There was a variety of factors that affected implementation, but research suggests that one of the main issues was a lack of time for district leaders to develop a common vision of learning and teaching to inform their work with teachers (Stein & D'Amico, 2002; Fullan, 2007). This line of research should serve as a caution to states and districts implementing the NGSS, as ensuring that leaders have a shared vision of an educational reform is a crucial element to its success

(McLaughlin and Talbert, 2002). My results suggest that leaders need to develop a vision of the NGSS that includes an emphasis on critique and reflects the differences between NGSS-aligned instruction and typical strategies.

Leaders' Sensemaking of the NGSS and Argumentation

Leaders' lack of understanding of the role of critique and some leaders' conceptions of the effectiveness of typical strategies necessitate consideration of why their visions of argumentation and the NGSS misaligned in such ways. The cognitive process of sensemaking offers a potential explanation. Sensemaking refers to the ways that individuals interpret and make meaning of new, unfamiliar ideas (Weick, 1995; Weick et al., 2005). Several recent studies have documented the varied ways leaders interpret the instructional changes intended by new reforms (e.g., Coburn, 2001; Coburn, 2005; Spillane, 2004). While educational research often attributes resistance to change as a key factor in the failed implementation of standards, literature about sensemaking (Spillane, 2004; Weick, 1995) and the findings from this dissertation suggest a different explanation for the NGSS. The leaders in this study overwhelmingly appeared to be supporters of the reform (Marz & Kelchermans, 2013), as they described positive views of the NGSS, strong beliefs about argumentation, and a willingness to implement it in their districts. In the open-ended survey items about their districts, most of the leaders discussed the need for teachers to move away from teacher-controlled direct instruction, toward a model better aligned with the goals of the NGSS. Such views likely reflect leaders' beliefs that the NGSS is in the best interest of students. However, they may also be the result of seeing the NGSS as a policy that can increase the visibility of science in districts and a way to make this typically marginalized subject (Spillane, 2005) more of a priority. However, leaders' enthusiasm for argumentation and the NGSS should not be confused with deep understandings of the changes it necessitates in science classrooms. When confronted with new information, sensemaking tends to cause individuals to notice what is most familiar and maintain "existing mental scripts rather than overhaul them" (Spillane, 2004, p. 78). Individuals focus on the familiar aspects and discount that which does not fit with existing understandings (Weick, 2005; Spillane, 2004). Spillane (2004) describes the ways district leaders in Michigan understood new state math standards related to problem solving as necessitating small changes in classroom instruction instead of the substantial shifts called for by the standards. This occurred because the leaders focused on surface features of the instruction related to problem solving instead of the deep transformations necessary for students to engage in this process. The leaders made sense of the standards in ways that fit their previous beliefs and experiences instead of overhauling their "knowledge scripts" (Spillane, 2004).

In attempting to understand the changes called for by the NGSS, some of the leaders in this dissertation likely did not disregard old notions of effective instruction and replace them with new ideas aligned with the NGSS. Instead, these leaders may have imposed small changes on their beliefs about science instruction that they believed represented more substantial shifts (Spillane, 2004; Weick, 1995). This helps to explain why some leaders believed strategies and benefits aligned with the NGSS were effective while simultaneously holding onto beliefs about typical instructional strategies. This also suggests that leaders may not have previously viewed critique as an essential element of science teaching and learning, and therefore failed to notice its essential role in the NGSS.

Sensemaking also connects to the finding that some leaders' perceptions of "hands-on" science aligned with some of the NGSS science practices, as well as some leaders' use of the term "inquiry" to describe effective science instruction. Leaders' use of these terms could be interpreted to signal their developing understandings of the ways instruction must change to meet the goals of the NGSS. However, it is also possible that leaders' sensemaking of the NGSS is causing them to expand on the traditional meanings of these terms (Zembal-Saul, 2009; Osborne, 2014) to include some of the science practices, such as engaging in investigations and analyzing data. Leaders may be "appropriating the labels" or "appropriating the surface features" (Grossman, Smagorinsky, & Valencia, 1999) of the science practices, making superficial changes rather than deeper conceptual shifts in their understandings of effective science instruction. The NGSS intentionally use the term "science practices" because "hands-on" and "inquiry" learning has typically only involved students in the doing of science skills, instead of making sense of natural phenomena (Osborne, 2014). As such, leaders' uses of these terms may signal a "tweaking rather than overhauling" (Spillane, 2004, p. 81) of knowledge, which is characteristic of sensemaking.

However, sensemaking does not occur in a vacuum. Individuals' sensemaking of policies interacts with contextual factors (Weick, 1995). As leaders interpret new standards and information, the meanings they construct depend on other factors in their environments. The findings from my third research question suggested that leaders' beliefs about the contexts in which they worked impacted their beliefs about alignment of instruction in their districts with argumentation more than their PCK or beliefs about argumentation. For example, two leaders who had similar argumentation beliefs discussed beliefs about conditions in their districts that appeared to influence their beliefs about alignment, such as beliefs about the differences between elementary and secondary science teachers and the amount of time that teachers had been engaged in argumentation instruction. This is an important consideration for leaders who design teacher and leader education experiences, as such professional development must account for beliefs about local conditions (Spillane, 1998) that impact how individuals come to understand new policies (Honig, 2006).

District Leaders' PCK for Argumentation

While leaders' beliefs suggest areas for their professional development, the results from the PCK instrument have important implications as well. While most PCK studies focus on teachers (e.g., Loughrin et al., 2001; van Driel, Beijarrd, & Verloop, 2001), researchers have begun to suggest that PCK is essential for instructional leadership as well (Brazer & Bauer, 2013). In 2003, Stein and Nelson introduced the concept of Leadership Content Knowledge (LCK) to explain how leaders transform their knowledge of a specific discipline to provide appropriate learning experiences for teachers. They asserted that PCK in at least one content area is essential for effective LCK. For district science leaders to design teacher education experiences that support teachers in developing PCK for science practices, which is essential to meeting the goals of NGSS (Osborne, 2014; National Academies of Sciences, Engineering & Medicine, 2015), then these leaders need to possess it as well.

Although the leaders in this dissertation demonstrated a range of PCK for argumentation, there were several areas that were more challenging for most leaders. Related to the structural aspects of argumentation, most leaders' choices on the multiple-choice items and responses to the open-ended questions suggested a lack of understanding about what counts as evidence and reasoning in argumentation, and a possible confusion of these constructs. Most leaders also struggled with the dialogical conception, specifically strategies to engage students in dialogical interactions to critique multiple claims. While research has only scratched the surface of the role of PCK for instructional leaders (Brazer & Bauer, 2013), it raises the question of whether many of the leaders in this study could design learning opportunities for teachers that would help them develop deep understandings of how to teach argumentation. For example, 30 leaders in this study were not able to identify that a student's argument lacked high quality evidence (Table 4.4). However, being able to identify student conceptions about content is essential to provide the appropriate feedback so that students can improve their understandings (Park & Oliver, 2008). Absent an ability to recognize student challenges with evidence, leaders may be challenged to design professional development that support teachers in developing this crucial skill (Stein & Nelson, 2003).

Research about effective argumentation professional development for teachers highlights the types of knowledge leaders need to support teachers in their instruction of the NGSS science practices. McNeill & Knight (2013) described a series of three workshops for teachers that were successful in developing their PCK for argumentation related to the structural elements. The leaders of these workshops selected texts and videos that demonstrated for teachers what counted as high quality argumentation in the classroom, suggested strategies for teachers to use with their students, and provided opportunities for teachers to use their developing knowledge in their own classrooms and reflect on their students' work. All of these design choices could have been impacted by the professional development leaders' PCK for argumentation. This suggests that many of the district leaders in this dissertation may need opportunities to develop their PCK for argumentation before beginning to design professional development for teachers.

Developing PCK

Leaders' sensemaking of NGSS and argumentation can in part account for the struggles leaders demonstrated with the PCK instrument. Magnusson et al. (1999) assert that teachers' PCK is a result of their knowledge being filtered through their beliefs about effective teaching of science. This helps to explain, for example, why leaders in this study who did not believe in the benefits of critique in argumentation struggled to recommend appropriate instructional strategies to engage students in critique. However, a simpler reason for leaders' struggles with PCK likely also exists: they have not had time to develop it. The NGSS is a new policy and PCK development is complex and time-consuming (Kind, 2009). The teachers in the McNeill and Knight (2013) study, for example, participated in workshops over a period of several months to develop their PCK for argumentation, and similar studies have investigated PCK development in teachers over the course of longer time periods (e.g., Avraamidou & Zembal-Saul, 2010). For this reason, research has found that more experienced teachers tend to have higher levels of PCK than beginning teachers (Lee et al., 2007). As such, investigating leaders' PCK in later stages of implementation of the NGSS is an important area for future research.

However, in addition to time, there is another challenge for leaders' development of PCK. Research suggests that experiences teaching specific subject matter to students can be crucial to developing PCK for that topic (van Driel, de Jong, & Verloop, 2001; Hashweh, 2005; Aavramidou & Zembal-Saul, 2010). Park and Oliver (2008) assert that

PCK develops as an interplay between “knowledge in action” and “knowledge in use” (p. 287), as teachers use their developing knowledge to instruct in their classrooms and reflect on their teaching. However, most leaders in this study indicated that they do not teach students in the classroom. As I will discuss below in my recommendations for professional development for leaders, to develop leaders’ PCK for argumentation will depend on leveraging other research-based methods. Observations of classrooms can be instrumental in this regard (Van Driel, de Jong, & Verloop, 2001).

Implications

Leaders in this study were enthusiastic about the NGSS and appeared committed to its implementation. They saw multiple benefits for students engaged in argumentation and realized a need for teachers to shift their instruction to meet the goals of the NGSS. However, leaders’ visions of the NGSS and their PCK for argumentation will likely impact the effectiveness of the learning experiences they design for teachers. Below I make suggestions for the design of professional learning for district leaders to support them in developing a vision of the NGSS that better aligns with the goals of these standards and helps them further develop their PCK for argumentation. I also consider broader policy implementation implications for districts.

Professional Development for District Leaders

For the NGSS to truly impact classroom instruction in ways that substantially change how science is taught and learned, leaders must first have opportunities to engage in professional development that enables more sustained sensemaking of these standards (Coburn, 2001; Spillane, 2004). Learning new instructional strategies or adopting new curricula is insufficient (Penuel et al., 2007); leaders must first grapple with the substantial ways that the NGSS differ from most current science instruction (NRC, 2015; Krajcik et al., 2014). Leaders must experience uncertainty and ambiguity about their understandings of effective science instruction compared to the NGSS (Allen & Penuel, 2015) so that they can begin the process of "discrediting and abandoning deeply held scripts" (Spillane, 2004, p. 157) and start to create new ones.

Opportunities for sensemaking of new standards, however, cannot be a solitary undertaking. Independently examining new standards rarely results in the restructuring of knowledge scripts (Spillane, 2004). Coburn's (2001) research into teachers' sensemaking of new reading policies highlights the key role of collaboration and social interactions in sensemaking. This research identified small, formal, heterogeneous groupings of individuals as key features that enabled teachers to engage in sensemaking that impacted their classroom instruction. Coburn (2001) found that while teachers often constructed informal networks, such groupings tended to be homogenous and did not expose individuals to the different perspectives they needed to "engage in the kind of framing and reframing that tended to surface, question, and at times shift assumptions" (p. 157). While more formal structures can falter when conversations focus on simply pleasing those in power, such collaborative experiences can also provide the conflict and discomfort necessary for effective sensemaking of new standards. Since district leaders, unlike teachers, likely have fewer colleagues in their direct vicinities, collaboration between districts or online professional development could be useful in this regard (Lock, 2006).

I suggest that framing such professional development for leaders around the concept of noticing (Sherin & Van Es, 2005) could help engage them in the sensemaking essential to changing their beliefs, and provide the resources for leaders to improve their PCK for argumentation. “Noticing” focuses on what individuals do and do not pay attention to and how they actively make sense of the myriad of activities in front of them (Sherin, Jacobs, and Philip, 2011). While there is not one specific design of professional development that focuses on noticing, the use of video vignettes has been shown to be useful (Sherin & Van Es, 2005). Such videos of classroom science instruction could support leaders in developing their abilities to attend and respond differently to students and teachers engaged in typical and NGSS-aligned instruction (Sherrin, Jacobs, & Philipp, 2011). Work by Sherin and van Es (2005) about mathematical teachers’ noticing demonstrates that over time, teachers’ discussions of what they notice, the evidence for their noticing, and their interpretations of instruction, can result in a change in their focus. Specifically, the teachers began to notice more about student thinking and discourse and the evidence teachers provided for their noticing supported them in connecting to new conceptions of effective mathematics instruction. For the leaders who participated in this dissertation, for example, a series of workshops focused on videos of students engaging in discourse in which they critique and build on each other’s arguments could offer opportunities for leaders to begin to notice the importance of critique in science instruction and the benefits to student engagement in such experiences. As leaders’ noticing of critique changes over time, they will hopefully begin to disregard their beliefs about the effectiveness of typical instructional methods and replace them with beliefs better aligned with the critiquing goals of the NGSS.

In addition to impacting beliefs, a focus on noticing also has the potential to affect leaders’ PCK for argumentation. van Driel, de Jong, & Verloop (2001) suggest that observing classroom instruction can improve teachers' abilities to notice student conceptions, a key aspect of PCK. In addition, research has found that as teachers' noticing of student conceptions shift, they learn to respond in different ways to meet the needs of the students (Jacobs, Lamb, & Philipp, 2010), the second aspect of PCK (Shulman, 1987). For leaders in this study who confused evidence and reasoning, for example, a focus in professional development on noticing students' evidence and reasoning could support them in understanding the differences between these constructs and develop strategies to respond to students' difficulties with them in their arguments.

However, while improving leaders' PCK for argumentation and providing opportunities to engage in sensemaking are crucial for leaders, professional development must also enable leaders to use their developing PCK to design productive professional development for teachers (Stein & Nelson, 2003). Research has extended the construct of noticing to the leadership of teachers, although as of yet, only related to mathematical content knowledge (Kazemi et al., 2011). Such findings suggest, however, that professional development focused on noticing can help leaders improve their abilities to facilitate professional development for teachers. Specifically, Kazemi et al. (2011) found that leaders improved their understandings of teachers' possible conceptions and developed strategies to support teachers' noticing of student thinking by viewing and discussing videos of teachers engaged in mathematical problem solving. Such opportunities could be useful for district science leaders to support them in designing professional development for teachers about the NGSS. For example, if leaders view videos of teachers learning about dialogical argumentation, they may notice patterns in teachers' conceptions about engaging students in discourse and critique. Leaders can then use what they noticed to design professional development that explicitly addresses common teacher conceptions, thereby better supporting teachers in developing strategies to engage students in dialogical argumentation.

Implementation of New Policies

The findings from this dissertation also offer some important considerations for districts and states implementing the NGSS. Policy documents and research call on districts to prioritize time, resources, and personnel for professional learning for teachers related to the NGSS (e.g., National Academies of Sciences, Engineering, and Medicine, 2015). Teacher professional development will be crucial (Reiser, 2013), but given the ways that leaders' framing of policies and understanding of new standards impacts implementation (Spillane, 2004; Coburn, 2006), my results indicate that districts must also prioritize resources for science leaders' professional learning.

In addition, the findings from this dissertation about the influence of beliefs about district-level factors on leaders' beliefs should serve a reminder of the complexities inherent in policy implementation and the ways that a multitude of variables impact whether and in what ways a policy is implemented (Honig, 2006; Penuel et al., 2009). Coherence in policy implementation is essential for the successful adoption of a new reform (Fuhrman, 1993), and such coherence has been shown to improve teaching and learning and drive student achievement (Newmann et al., 2001). Therefore, in districts adopting the NGSS, the messages to teachers about effective science teaching and learning, the curricula bought or developed, and the professional development offered, must all reflect the ambitious vision of science education embodied in the NGSS. If teachers participate in professional development, for example, that emphasizes the role of critique and debate in argumentation, but district or school policies encourage students to always raise their hands and talk to the teacher, then this lack of coherence will make it difficult for science instruction to meet the goals of the NGSS. This further speaks to the need for districts to ensure that science leaders have visions and knowledge of the NGSS that align with the policy.

However, coherence should not simply be considered an outcome of policy implementation. Instead, Honig and Hatch (2004) argue that coherence is a process that leaders at the school and district level continually engage in as they implement and support reforms. As leaders manage new polices and demands on resources, they must work to maintain a focus on the key educational goals. I suggest that for districts implementing the NGSS, district science leaders can play an important role in advising district and school leaders, and marshaling the necessary resources to ensure coherence that enables the successful implementation of the NGSS.

Limitations and Future Research

This dissertation focused on the beliefs and PCK of district science leaders about scientific argumentation. My findings suggest that some leaders' work with teachers could be impacted by beliefs that misaligned with their visions of the NGSS, and their challenges with PCK for argumentation. However, I did not observe these leaders as they engaged in leadership tasks such as designing professional development, and therefore cannot establish a link between their beliefs or PCK and their leadership of teachers. While research has found connections between leaders' beliefs and instructional leadership (e.g., Coburn, 2001), beliefs are complex and do not necessarily align with actions (Zohar, 2008; Mansour, 2013). In addition, this dissertation is one of the first attempts to measure leaders' PCK. While research suggests that PCK is an important component of the knowledge base for instructional leadership (Stein & Nelson, 2003; Brazer & Bauer, 2013), there is little research that empirically supports such assertions. This is an important area for future research so that such theories can be validated and more robust understandings of the role of PCK in leadership can be developed. The development of additional methods for exploring leaders' PCK and LCK is also greatly needed, such as instruments and observational protocols that target leaders' abilities to notice and provide appropriate feedback to teachers about the science practices.

While the sample of leaders in this dissertation represented a range of states that adopted the NGSS, the results may not be generalizable to other leaders in these states. State contexts can be important (McLaughlin & Talbert, 1993), but my findings and related research (e.g., Honig, 2006) indicate that district level factors also play a role in leaders' beliefs and PCK. For example, two leaders in the same state can work in districts with different priorities and policies that impact their beliefs and PCK. Future research should explore the nature of these influences to determine more specifically the factors that impact the implementation of the NGSS and methods for effectively supporting leaders.

This dissertation is one of the few pieces of research to date to focus on district science leaders. Research suggests an important role for districts in policy implementation (e.g., Elmore & Burney, 1997; Firestone, 2005), yet few studies consider leaders at this level. Additional work in this area is essential to build an understanding of the roles, responsibilities, and influences of such individuals and the ways in which they enact leadership for the NGSS. My study suggests that science leaders can be proponents of the NGSS and enthusiastic about its implementation, especially related to argumentation. However, for the NGSS to be successful, district science leaders must have access to high-quality professional development so that their visions and understandings of the NGSS align with the ambitious goals set forth by this policy.

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APPENDIX A: SURVEY

A1. Consent Section
A2. Background and Demographic Items
A3. Belief Likert Scale and Open-Ended Items
A4. PCK Multiple-Choice and Open-Ended Items
A5. Final Survey Questions

A1. Consent Section

Thank you for completing this survey for district-level instructional leaders about the Next Generation Science Standards (NGSS) and scientific argumentation. This survey should take you about 45 minutes and as thanks for your completion, you will receive a $50 Amazon gift card. The next page describes in more detail the research associated with this survey and asks for your permission to participate in this research study. If you agree to participate then the survey will begin on the following page.

You are being asked to participate in an NSF-funded research study about the NGSS science practice of scientific argumentation. You were selected to participate in this project because of your expertise related to science education and your position as a district-level science instructional leader.

The purpose of this study is to explore the types of supports districts may need related to adopting NGSS and implementing scientific argumentation in the classroom. Participants in this study are individuals from states that have adopted NGSS and who are employed at the district level supporting k-12 teachers in science education in district schools. Participants may have other roles in the district as well, but must have some responsibility related to science curriculum development, science professional development, or working with science teachers in some way.

This study will be conducted through an online survey. This survey should take about 45 minutes to complete. In addition, for participants that are also interested in participating in a phone interview, there will be an opportunity at the end of the survey to indicate that interest.

You can be compensated for the time you take to complete this survey through a $50 Amazon gift card. If you would like to receive the gift card, we will ask for your contact information on the last screen of the survey. This information will be separated from your survey responses. There are no costs to you associated with your participation.

This Principal Investigator will exert all reasonable efforts to keep your responses and your identity confidential. The records of this study will be kept private. All participant names will be removed from the surveys and interviews. Number codes will be assigned to each individual and all information collected will be kept confidential. In any sort of report we may publish, we will not include any information that will make it possible to identify a participant. Please note that regulatory agencies, the Boston College Institutional Review Board, and Boston College internal auditors may review research records.

You participation is voluntary. If you choose not to participate it will not affect your relations with Boston College. You are free to withdraw for any reason. There are no penalties for withdrawing. There are no direct benefits to you, but you may feel gratified knowing that you helped further the scholarly work in this research area. There are no expected risks. This study may include risks that are unknown at this time.

If you have questions or concerns concerning this research you may contact the Principal Investigator, Dr. Katherine McNeill, at 617-552-4229 or kmcneill@bc.edu. If you have questions about your rights as a research participant, you may contact the Office for Research Protections, Boston College, at 617-552-4778 or irb@bc.edu.

This study was reviewed by the Boston College Institutional Review Board and its approval was granted on May 22, 2015.

If you agree to the statements above and agree to participate in this study, please press the "Consent Given" button below.

- Consent Given
- Consent Not Given

A2. Background Items and Demographic Items

Q3 Are you currently employed as a district-level administrator, supervisor, or curriculum coordinator?
- Yes
- No

Q4 Are your responsible for science education, science curriculum, and/or supervision of science teachers as part of your current job?
- Yes
- No

Q5 Please select the state in which you currently work:
- California
- Delaware
- Illinois
- Kansas
- Kentucky
- Maryland
- Nevada
- New Jersey
- Oregon
- Rhode Island
- Vermont
- Washington D.C.
- Washington State
- Other

In this first part of the survey we would like to learn a little more about you.

Q7 Which type of teaching credentials do you hold? (Check all that apply)
- None
- Elementary
- Middle School or Secondary Science
- TESOL/ESOL/ESL
- SPED
- Other (please specify) ____________________

Q8 What type of administrative credentials do you hold? (Check all that apply)

- None
- Assistant Principal/Principal
- Assistant Superintendent/Superintendent
- Coordinator or Content Supervisor
- Other (please specify) ____________________

Q9 What is the highest degree that you hold in education?

- None
- Bachelors
- Masters
- Doctorate

Q10 What is the highest degree that you hold in science?

- None
- Bachelors
- Masters
- Doctorate

Q11 In total, how many years have you taught in a K-12 classroom? (Please include this year if you currently teach a class.)

- None
- 1
- 2-5
- 6-10
- 11-15
- 16-20
- more than 20

Q12 In total, how many years have you taught science in a K-12 classroom? (Please include this year if you currently teach a class.)

- None
- 1
- 2-5
- 6-10
- 11-15
- 16-20
- more than 20

Q13 At which grade levels have you taught science? (Check all that apply.)

- Lower elementary (K-2)
- Upper elementary (3-5)
- Middle School (6-8)
- High School (9-12)
- Undergraduate
- Graduate

Q14 In total, how many years have you been a district administrator? (Please include this year.)

- 1
- 2-5
- 6-10
- 11-15
- 16-20
- more than 20

Q15 In total, how many years have you been an administrator in your current district? (Please include this year.)

- 1
- 2-5
- 6-10
- 11-15
- 16-20
- more than 20

Q16 In total, how many years have you been an administrator in your current state? (Please include this year.)

- 1
- 2-5
- 6-10
- 11-15
- 16-20
- more than 20

Q17 Which of the following are responsibilities that you have in your current position? (Check all that apply.)

- Curriculum development
- Disseminating information to teachers
- Analyzing data to inform instruction
- Conducting professional development
- Working one on one with teachers
- Teaching K-12 students
- Evaluating teachers
- Other (please specify) ____________________

Q18 In addition to science, what other content areas are you responsible for? (Check all that apply.)

- None. I am only responsible for science.
- Math
- Engineering
- Technology
- English/Language Arts
- Social Studies
- Other (please specify) ____________________

Q19 In which type of school district do you currently work?

- Urban
- Suburban
- Rural

Q20 What percentage of students in your district are eligible for free or reduced price lunch?

- Less than 25%
- 25-50%
- 51-75%
- more than 75%

Q21 What percentage of the students in your district are identified as second language learners?

- Less than 25%
- 25-50%
- 51-75%
- more than 75%

Q22 Has your state adopted the Next Generation Science Standards (NGSS)?

- Yes
- No
- I don't know

Q23 When will teachers in your district be expected to teach NGSS?

- They already are
- Next school year
- In the next few years
- I do not know

Q24 How many workshops, professional development sessions, or classes have you participated in about scientific argumentation?
- None
- 1
- A few
- Many

Q25 How many workshops, professional development sessions, or classes have you designed or led about scientific argumentation?
- None
- 1
- A few
- Many

Q26 How knowledgeable do you believe you are about the types of instruction scientific argumentation requires in the classroom?
- Not knowledgeable
- Somewhat knowledgeable
- Knowledgeable
- Very knowledgeable

Q27 Which race(s) do you identify with? (You may choose more than one option.)
- White
- Hispanic or Latino
- Black or African American
- Native American or American Indian
- Asian/Pacific Islander
- Other (please specify) ____________________
- I do not wish to respond

Q28 Which gender do you identify with?
- Male
- Female
- Other (please specify) ____________________
- I do not wish to respond

Q29 What is your current job title?

A3. Likert Scale and Open-Ended Belief Items

The second section of this survey focuses on your ideas about high quality science instruction, scientific argumentation, and the work in your district. There are 4 pages with these questions.

Q30 Please indicate how strongly you believe in each of the following statements. (Strongly Disagree, Disagree, Agree, Strongly Agree)

	Strongly Disagree	Disagree	Agree	Strongly Agree
Hands-on activities are the best way for students to learn science.	•	•	•	•
During class discussions students should persuade each other of their ideas.	•	•	•	•
Scientific argumentation is an effective way to develop students' critical thinking skills.	•	•	•	•
Learning science ideas (content) should be the main goal of science class.	•	•	•	•
Critiquing texts and ideas is an important part of science learning.	•	•	•	•
Scientific argumentation is an effective way to develop students' reasoning and problem-solving skills.	•	•	•	•
The scientific method should be a focus of science instruction.	•	•	•	•
Science	•	•	•	•

instruction should engage students in using science ideas to explain evidence.				
Scientific argumentation is an effective means by which to develop students' language skills (reading, writing, and speaking).	•	•	•	•
Teachers should present scientific information to students.	•	•	•	•

Q33 What do you think good science instruction looks like?

Q31 Please indicate how strongly you believe in each of the following statements. (Strongly Disagree, Disagree, Agree, Strongly Agree)

	Strongly Disagree	Disagree	Agree	Strongly Agree
Students should consider multiple scientific claims as part of learning science.	•	•	•	•
Scientific argumentation is an effective way for students to learn and practice literacy strategies.	•	•	•	•
Teachers should ensure that students take turns during class discussions so all students have a chance to present their ideas.	•	•	•	•
Scientific arguments are best constructed by allowing students to build on each other's ideas.	•	•	•	•
Scientific argumentation is an effective way to increase students' interest in science.	•	•	•	•
Class discussions are most effective when they occur after students	•	•	•	•

have learned the science content.				
Students should use data to support or refute scientific claims.	•	•	•	•
Scientific argumentation is an effective way to help students consider multiple views about science.	•	•	•	•
Teachers should always provide feedback to students after they speak in class.	•	•	•	•

Q34 What do you believe are the benefits to students, if any, of engaging in scientific argumentation? Why do you think these are benefits?

Q37 What do you believe are the drawbacks to students, if any, of engaging in scientific argumentation? Why do you think these are drawbacks?

Q32 Please indicate how strongly you believe in each of the following statements. (Strongly Disagree, Disagree, Agree, Strongly Agree)

	Strongly Disagree	Disagree	Agree	Strongly Agree
During class discussions, students should question each other's ideas.	•	•	•	•
Scientific argumentation is an effective way to encourage student participation in class discussions.	•	•	•	•
Laboratory activities are most effective for students after they have learned specific content.	•	•	•	•
Engaging students in using scientific principles to explain evidence is an important part of science instruction.	•	•	•	•
Scientific argumentation is an effective way for students to learn science content.	•	•	•	•
Teachers should explain an idea to students before having them consider evidence that	•	•	•	•

relates to that idea.				
Scientific argumentation skills that students learn, develop, and use are applicable outside the science classroom.	•	•	•	•
At the beginning of instruction of a new science idea, students should be provided with definitions for new scientific vocabulary that will be used.	•	•	•	•
Student-to-student interactions are an important part of scientific argumentation in the classroom.	•	•	•	•
Scientific argumentation is an effective way to increase students' understanding of how scientists work.	•	•	•	•

Q91 Overall, the science instruction in my district is closely aligned with the goals of scientific argumentation.

- Strongly disagree
- Disagree
- Agree
- Strongly Agree

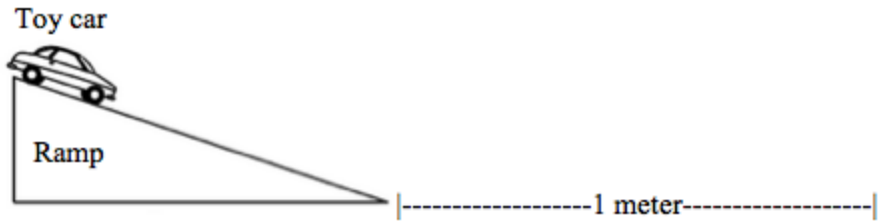
Q35 In what ways does the science instruction of teachers in your district align with the goals of scientific argumentation?

Q38 In what ways does the science instruction of teachers in your district not align with the goals of scientific argumentation?

A4. PCK Multiple-Choice and Open-Ended Items

Vignette #1: Mr. Cedillo's Class

Mr. Cedillo's 7th grade science class is doing a unit on force and motion. Near the middle of the unit his students explore friction by analyzing the data table from an investigation they conducted that answered the question: Which type of surface material will allow a toy car to have the greatest average speed? The students let a toy car go from the top of a ramp and timed how long it took to travel 1 meter after reaching the bottom of the ramp, over four different surface materials: felt, top of lab table, sand paper, and ice (see image below).



They then calculated the toy car's average speed by dividing the distance over the time. The table below shows the students' experimental results.

Surface Material	Distance Traveled (meters)	Time (seconds)	Average Speed (meters/seconds)
Felt	1.0	2.4	0.42
Top of lab table	1.0	1.5	0.67
Sand paper	1.0	2.2	0.45
Ice	1.0	1.0	1.0

Ellen raises her hand in class and states the following argument: "The car on the ice will always go the fastest. I've been in a car driving on ice, and I know a car can skid because ice is the smoothest surface. My dad has a really big truck and it doesn't slide as far, so maybe next time we should try this experiment with larger cars."

1. Mr. Cedillo should respond by saying:
    a. "Interesting point, Ellen. Does anyone have similar reasoning?"
    b. **"Great connection. Can anyone suggest data to support this?"**
    c. "Nice argument. What additional evidence could Ellen add?"
    d. "Well done. Does anyone else want to share their argument?"

Mr. Cedillo next asks his students to engage in oral argumentation, during which they debate their ideas about the relationship between surface material and average speed. The excerpt below is from the beginning of their conversation.

Maya: “My claim is that rough materials cause cars to go faster.”

Elana: “I think the data table shows that rough materials make cars go slower.”

Ben: “Well, I think there are lots of reasons a car would go faster or slower.”

2. Mr. Cedillo should speak up and encourage his students to:
    a. Debate other possible reasons a car might go faster or slower
    b. Focus the class discussion on the scientifically accurate claim
    c. Research and include what expert scientists say about friction
    d. Convince their fellow classmates that their claim is the best

After Mr. Cedillo intervenes, Elizabeth speaks.

Elizabeth: “I think the surfaces with more friction caused the cars to slow down sooner. This means that they will take longer to go 1 meter. Friction is when two surfaces rub against each other creating a force in the opposite direction an object is moving. Something has more friction when it is rougher.”

3. Elizabeth:
    a. Should explain her argument’s relevant science concept
    b. Needs to incorporate evidence to support her claim
    c. Requires help stating an accurate claim about the surfaces
    d. Does not require any modifications to her argument

For homework, Mr. Cedillo asks the students to write out their arguments. Gustavo writes the following argument: *Our car went the fastest on ice also. It had a speed of 1.0 meters per second. This was faster than the felt, where the car averaged 0.42 meters per second. This is because of friction.*

4. Mr. Cedillo should say to Gustavo:
    a. “Describe how you calculated the speed of the toy car.”
    b. “Identify scientific principles that link to your claim.”
    c. “Clarify how the evidence connects to your claim.”
    d. “This argument looks good, no further work needed.”

5. What are two strategies that you believe are effective for helping students **engage in oral argumentation**? Explain your rationale for why you believe these strategies are effective.

Vignette #2: Mr. Luongo's Class

Mr. Luongo asked his students to read an article and construct a scientific argument about whether *Elysia chlorotica*, a unique species of sea slug, should be characterized as a plant or animal. The article described the ways in which the slug exhibits characteristics of both plants, such as performing photosynthesis, and animals, such as being heterotrophs. Two of his students' written arguments are provided below:

Beatriz: *I think that Elysia chlorotica should be classified as plants. The article we read said that these slugs eat algae and once they eat those algae they have the genes for performing photosynthesis. That's why I think that Elysia chlorotica should be considered a plant more than an animal.*

Joao: *I think that the green sea slugs Elysia chlorotica should be considered animals. I've seen slugs when I play in the park and I know that they move and eat like other animals do. Plants are autotrophs, which means they make their own food. Animals are heterotrophs, which means that they need to eat other things to live.*

1. After reading these students' responses, Mr. Luongo should:
    a. **Tell students to critique each other's arguments about the sea slug's classification**
    b. Encourage students to read more about distinguishing between plants and animals
    c. Remind students that personal observations do not count as evidence for a claim
    d. Have students analyze a scientific video that explains why this sea slug is an animal

Mr. Luongo gives the students an opportunity to edit their arguments. Beatriz adds the following sentences to her argument: *I remember learning earlier this year that plants, like trees and lily pads, perform photosynthesis. So if this slug does photosynthesis it must be a plant.*

2. By adding these sentences, Beatriz:
    a. Used appropriate evidence to support her claim
    b. Weakened the claim she made in her argument
    c. **Explained why the evidence supported the claim**
    d. Incorporated a more scientifically accurate claim

Mr. Luongo then pairs up students to edit each other's arguments. While walking around the room he hears the following interaction:

Leah: "Claire, you wrote that this slug becomes a plant after eating algae? You're using X-men to support your claim?"

Claire: "Yeah! Remember the character Rogue? She takes other mutants' powers and this slug basically does the same with algae—after eating algae it can do photosynthesis. So like Rogue this slug becomes what it takes in, in this case a plant."

Leah: "Oh I guess you're right. I should add that as more supporting evidence for my claim too!"

3. After hearing these students' conversation Mr. Luongo should:
    a. **Prompt students to review the class description of what counts as evidence**
    b. Encourage students to explain the scientific reasoning behind this evidence
    c. Remind students to incorporate as many pieces of evidence as possible
    d. Have students consider how this evidence could support the counter claim

After talking with her group members, Sam and Jan, Daniela writes the following argument:

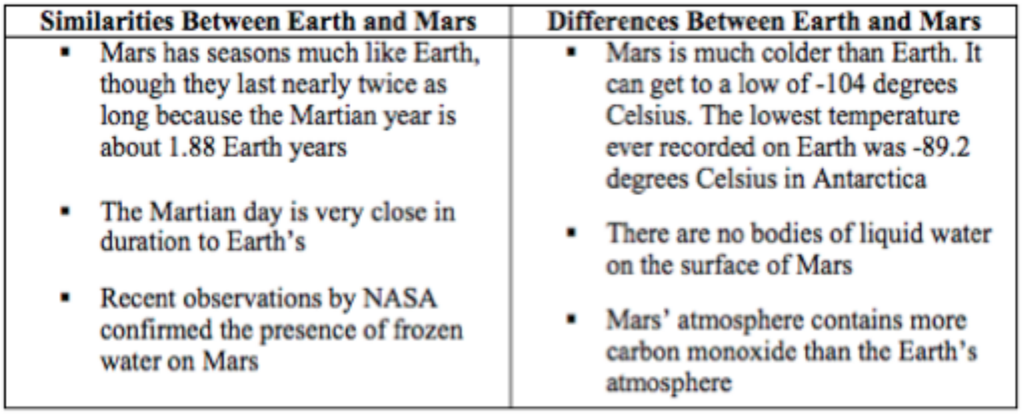
Elysia chlorotica could be either a plant or an animal. Sam thought Elysia chlorotica could be an animal because it eats other organisms. Animals get their energy from consuming other species. But Jan thought it could be a plant because it performs photosynthesis. Photosynthesis allows plants and algae to use energy from the sun to create sugar.

4. Daniela needs help:
    a. Including scientific reasoning in her written argument
    b. Critiquing alternative explanations about this species
    c. Understanding how photosynthesis occurs in organisms
    d. Distinguishing between plant and animal characteristics

5. What do you think are the benefits and drawbacks to Mr. Luongo's approach of having students debate a topic with multiple claims? Explain.

Vignette #3: Ms. Strong's Class

Ms. Strong's students are preparing for a science seminar in which they will engage in oral argumentation to consider whether or not humans could survive in settlements on Mars. Before taking part in the science seminar, the students compile the following pieces of information into a large table on a poster to display in the front of the room:



Similarities Between Earth and Mars	Differences Between Earth and Mars
▪ Mars has seasons much like Earth, though they last nearly twice as long because the Martian year is about 1.88 Earth years ▪ The Martian day is very close in duration to Earth's ▪ Recent observations by NASA confirmed the presence of frozen water on Mars	▪ Mars is much colder than Earth. It can get to a low of -104 degrees Celsius. The lowest temperature ever recorded on Earth was -89.2 degrees Celsius in Antarctica ▪ There are no bodies of liquid water on the surface of Mars ▪ Mars' atmosphere contains more carbon monoxide than the Earth's atmosphere

To get her students ready for the science seminar, Ms. Strong has them use the table to write arguments. Alicia and Thomas write the following arguments:

Alicia: *I don't think humans can survive on Mars. The chart shows that Mars can get much colder than Earth and I saw a show on the Discovery Channel about the special clothes scientists have to wear when they do experiments in Antarctica because of the cold. It would be really awful to wear these clothes all the time just to go outside and it would cost a lot of money to get everyone these clothes.*

Thomas: *I think that settling on Mars would be great for humans. Days on Mars and Earth are almost the same length so we wouldn't have to change watches and clocks. Mars also has seasons like Earth so we'd have those too but they'd just be twice as long. Imagine how long summer break would be! No school for almost six months. Awesome.*

1. What are the strengths and weaknesses of how Alicia explains why her evidence supports her claim? Why?

2. After reading Alicia and Thomas' responses, Ms. Strong should begin by:
    a. Having students collect more numerical data about the planets under study
    b. Telling students to critique each other’s claims about human survival on Mars
    c. Asking students to analyze their current understanding of the scientific topic
    d. Encouraging students to organize the evidence in the table with a Venn Diagram

After writing arguments, Ms. Strong’s students engage in the science seminar. During the discussion the following exchange takes place:

Alex: “I think we could live on Mars. It would be awesome!”

Melanie: “My claim is the opposite of Alex’s. I don’t think that humans could live on Mars.”

Alex: “Why not? What’s your evidence?”

Melanie: “Well there aren’t any bodies of water on Mars’ surface and humans need water to live.”

Tina: “There might not be lakes and oceans on Mars like there are here on Earth, but I still agree with Alex because NASA scientists saw frozen water on Mars so humans could use that to live.”

Melanie: “Yeah, but how much water did they find? Did they measure how much there is?”

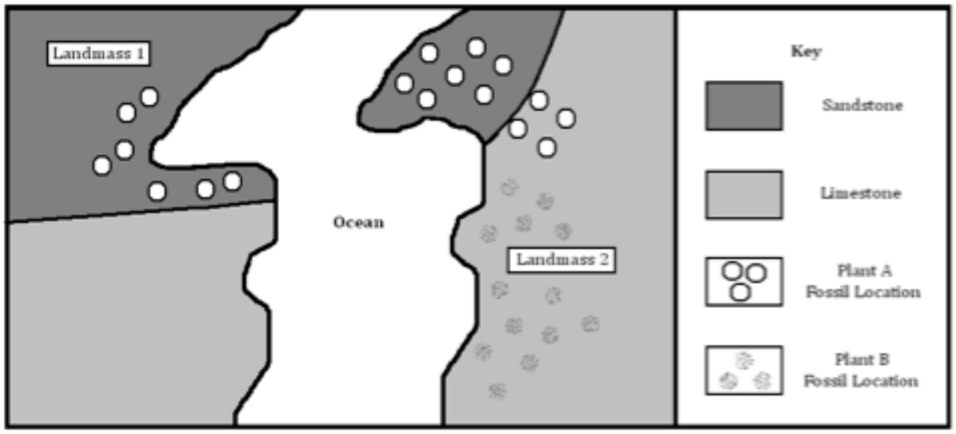
3. What could have Ms. Strong said before beginning this science seminar to encourage Melanie, Alex and Tina to have this type of discussion?
    a. "The purpose behind a science seminar is for everyone to share their ideas.”
    b. “The objective of a scientific argument is to use all the evidence in the data table.”
    c. "The point of this seminar is to make sure we all understand your argument.”
    d. “The goal of argumentation is to convince each other of the strength of a claim.”

4. By having students engage in a science seminar, Ms. Strong's main goal is to help students:
    a. Develop more interest in the seminar topic
    b. Generate accurate answers to the question
    c. Evaluate their classmates’ different claims
    d. Practice sharing out ideas with their peers

5. Later in the science seminar Justin says, "Humans couldn't live on Mars because its atmosphere has carbon monoxide." If no other students respond, after an appropriate wait time, Ms. Strong should say:
    a. "Explain how the data supports your claim”
    b. “What are some key elements of a strong claim?”
    c. "We need some quantitative data for this idea”
    d. “What gasses can we find in the atmosphere?”

Vignette #4: Ms. Alves’ Class

Ms. Alves’ 6th grade science class is near the end of a unit about plate tectonics. She gives her students the following diagram.



She then asks them to write scientific arguments answering the question: Do you think these two land masses have always been in the same location or do you think they were once in different locations? Before writing their arguments, Ms. Alves has the students turn and talk with a partner.

She hears Sofia say the following: “I think these two landmasses were not always in the same location. They were probably connected without any ocean between them. I mean, look at the shapes of the masses. They look like they once fit into each other, like a puzzle. And remember how last week we read about Pangaea and how there used to be one big supercontinent on Earth?"

1. What are the strengths and the weaknesses of the evidence Sofia uses in her argument? Explain.
2. Sofia's argument:
    a. Needs a more complete claim about the movement of the landmasses
    b. Should include quantitative evidence so that it will be more convincing
    c. Lacks an explanation of how the science concept supports her answer
    d. Contains an accurate rebuttal that is relevant to the landmass diagram

After writing their arguments, Ms. Alves groups students with opposing claims together and asks them to provide each other with constructive feedback. Ms. Alves notices that students are not critiquing each other's arguments.

3. Which of the following strategies would help her students do so?
    a. Have each student use a rubric to evaluate their own scientific argument
    b. Model what counts as appropriate high-quality evidence for the strongest claim
    c. Do a mini-lesson to demonstrate how to write a convincing scientific argument
    d. Show the students a video of a scientist questioning another scientist's claim

While monitoring students' discussions about their arguments, Ms. Alves hears Nora, Lucas and Maxwell have the following conversation:

Maxwell: "Well, I wrote that I think these two landmasses were always in the same location."

Nora: "I don't agree with you. I think they were once connected and then moved apart over millions of years. Just look at the landmasses' shapes. They obviously once went together."

Maxwell: "Maybe, but what about the other pieces of evidence, like the fossils? What do you think Lucas?"

Lucas: "I'm not sure. What if an asteroid hit the Earth and caused the ocean to form there?"

4. Ms. Alves should consider the start of this argumentation discussion to be:
    a. Unsuccessful because the students didn't address all the possible pieces of evidence
    b. Unsuccessful because Lucas does not have a chance to share a claim with his peers
    c. Successful because students are trying to convince each other of the strongest claim
    d. Successful because Lucas introduced additional evidence about asteroids at the end

The students' conversation continues:

Maxwell: "Nora you only mentioned one of the fossils from the picture but not all of the plant fossils are on both landmasses. 'Plant A' fossils are on both, but the 'Plant B' ones are only on Landmass 2."

Nora: "So what? That doesn't mean I'm wrong. Both plants didn't necessarily grow before they separated. Maybe 'Plant B' grew after the landmasses had already separated."

Maxwell: "I don't agree. I think all of the plant fossils were from the same time."

5. One reason that Ms. Alves should consider this a successful argumentation interaction between Maxwell and Nora is:
    a. Nora and Maxwell displayed in depth fossil knowledge
    b. Maxwell demonstrated that he will stand by his claim
    c. Maxwell and Nora discussed only high quality evidence
    d. Nora incorporated new evidence into her argument

A5. Final Survey Items

Thank you for completing this survey! To receive your $50 Amazon gift card, please enter your name and mailing address below. Please know that this information will be removed from your responses to ensure your anonymity. Please enter your full name:

Q89 Please enter your mailing address:

Q75 Would you be willing to participate in a 30-45 minute follow-up telephone interview? If selected, you will receive an additional $50 Amazon gift card to compensate you for your time.

- Yes, please e-mail me at the following address to set up an interview: ____________________
- No, I am not interested.

APPENDIX B: INTERVIEW PROTOCOL

Thank you for taking the time to speak with me today. I am conducting research about scientific argumentation. I would like to interview you about argumentation given your role as a district science leader. Do you have any questions for me? (*pause and wait for response)*. Is it ok if I tape record our conversation? (*pause and wait for response*). Great. Also, I am going to ask for your name so that I can link the interview to your survey responses, but any identifying information will be removed from the analysis to maintain confidentiality. Is that okay? *(pause and wait for response).* Now I am going to turn on the tape recorder, ask you your name, and then ask you again if it is ok if I tape record our conversation.

Please state your name.

Is it okay if I tape record our conversation?

- What do you think good science instruction looks like?
    - PROBE: What are students doing?
    - PROBE: What are teachers doing?

- What types of experiences do you think students need to have in the classroom to learn science?
    - PROBE for definitions to terms such as "inquiry" "science practices" "doing science" "critical thinking" etc.

- What does it mean for students to engage in "hands-on" science experiences?
    - PROBE: What are students doing?
    - PROBE: What are teachers doing?

- Now, I would specifically like to talk about scientific argumentation. What does a classroom engaged in argumentation look like?
    - PROBE: What are students doing?
    - PROBE: What are teachers doing?

- What do you believe are the benefits to students, if any, of engaging in scientific argumentation?
    - Can you tell me a little more about why you see these as benefits for students?

- What do you believe are the drawbacks to students, if any, of engaging in scientific argumentation?
    - Can you tell me a little more about why you see these as drawbacks for students?

- Do you think the instruction in your district needs to change to align with the goals of argumentation?
    - If so, in what ways?
    - If not, why not?

- What are you current and future plans to support teachers in your district with scientific argumentation? Why do you think this is important?

- Are there any resources or other supports that would better help you support your teachers in your district? If yes, what are they?

- Is there anything else you would like to share with me about NGSS, argumentation, or your district?

Thank you very much for your time. I will be mailing you a second Amazon gift card.

APPENDIX C: OPEN-ENDED PCK ITEMS CODING SCHEMES

Coding Scheme 1 (Mr. Cedillo)

Question: What are two strategies that you believe are effective for helping students engage in oral argumentation? Explain your rationale for why you believe these strategies are effective.

Category	Level 0	Level 1	Level 2

Strategies for engaging in oral argumentation	The leader does not address this topic
	OR
	The leader provides strategies that will not support engaging students in debate about a claim (such as strategies that encourage students to use appropriate vocabulary, strategies to ensure students have sufficient evidence, or general presentation strategies)
	OR
	The leader provides strategies that solely focus on the
		The leader states **one** appropriate strategy for engaging students in oral argumentation.
		OR
		The leader states a combination of appropriate and inappropriate strategies.
		
		Appropriate strategies might include:
		• Asking some students to play devil's advocate
		• Using a topic that has multiple possible claims
		• Providing students with a guiding question that elicits debate
		• Modeling student-to-student talk in terms of the dialogic components of argumentation
		• Using sentence starters such as "I agree with… because…" or "I disagree with…. Because …" or "Could you explain…?"
		    • Do not code if the sentence starters the teacher provides as examples focus on argument structure (e.g. "My claim is ____ and my evidence is _____")
		    • Do not code if teacher does not provide sample sentence starters
		• Developing classroom
			The leader states **two** appropriate strategies for engaging students in oral argumentation. Leaders do not state any inappropriate strategies to receive this code.
			
			Appropriate strategies might include:
			• Asking some students to play devil's advocate
			• Using a topic that has multiple possible claims
			• Providing students with a guiding question that elicits debate
			• Modeling student-to-student talk in terms of the dialogic components of argumentation
			• Using sentence starters such as "I agree with… because…" or "I disagree with…. Because …" or "Could you explain…?"
			    • Do not code if the sentence starters the teacher provides as examples focus on argument structure (e.g. "My claim is ____ and my evidence is _____")
			    • Do not code if teacher does not provide sample sentence starters
			• Developing classroom routines or a classroom culture of argumentation

	structure of arguments (i.e. CER) and not how to *use* this structure to engage in debate (such as ways to understand how data supports a claim being made) OR The leader mentions something vague, like using a visual organizer, or generally putting students into groups without discussing how these strategies would target specific dialogic conceptions	routines or a classroom culture of argumentation that encourages or supports debate (must be specific about how routine supports oral argumentation). For example, encouraging students to talk to one another instead of routing the conversation through the teacher • Allow for “productive silence” or wait time • As a teacher, physically remove yourself from the space in which students are debating. The MECM video calls this “stepping back” during the science seminar • Allow students to correct each other’s misconceptions if they arise during discussion • Use an activity, like a science seminar, to get students to interact with one another • Having students engage in a shared experience so that they all have familiarity with the topic being debated	that encourages or supports debate (must be specific about how routine supports oral argumentation). For example, encouraging students to talk to one another instead of routing the conversation through the teacher • Allow for “productive silence” or wait time • As a teacher, physically remove yourself from the space in which students are debating. The MECM video calls this “stepping back” during the science seminar • Allow students to correct each other’s misconceptions if they arise during discussion • Use an activity, like a science seminar, to get students to interact with one another • Having students engage in a shared experience so that they all have familiarity with the topic being debated
Rationale for	The leader does not address this topic OR The leader provides a rationale that is not appropriate for argumentation	The leader states a rationale that supports only **one** of the strategies provided in the response. This rationale should include one of the following: • Increase/support/encourage/promote student-to-student talk • Evaluating multiple claims that provide students with a need to engage in argumentation	The leader states one rationale that supports **both** strategies provided in the response OR The leader states **two different** rationales, each supporting a different strategy provided in the response. These rationales should include one of the following: • Increase/support/encourage/promote student-to-student

strategies	OR The leader discusses a big idea about argumentation that is unrelated to the strategies s/he provided in response to this question. OR Leader discusses how the strategy will increase participation, or get more students to talk, or make students more comfortable talking	• Seeing there is not one right answer • Trying to convince other students of their claim or argument • Revising and/or strengthening arguments or changing ideas after interacting with peers • Previously written/discussed questions/ideas provides students with tools to use when articulating their arguments and engaging in the process during the debate • Helps students develop an understanding that science knowledge is constructed and revised over time through these social practices	talk • Evaluating multiple claims that provide students with a need to engage in argumentation • Seeing there is not one right answer • Trying to convince other students of their claim or argument • Revising and/or strengthening arguments or changing ideas after interacting with peers • Previously written/discussed questions/ideas provides students with tools to use when articulating their arguments and engaging in the process during the debate • Helps students develop an understanding that science knowledge is constructed and revised over time through these social practices

Coding Scheme 2 (Mr. Luongo)

Question: What do you think are some <u>benefits</u> and <u>drawbacks</u> to Mr. Luongo's approach of having students debate a topic with multiple claims? Explain.

Category	Level 0	Level 1	Level 2
	Leader does not address this topic. OR Leader provides a vague response, such as:	Leader's response addresses **one** benefit. OR The leader states a combination of appropriate <u>and</u> inappropriate or vague	Leader's response addresses **two or more** benefits. Leaders <u>do not</u> state any inappropriate benefits (if any inappropriate benefits, code as Level 1).

Benefits	• Makes students think • Promotes critical thinking • It is good for all students • It is engaging for students • Discussions are good in class OR Leader states students engage in argumentation but does not explain how/why: • “Students have a change to engage in argumentation” OR Leader provides an inappropriate response that is focused on argument structure, such as: • Encourages students to use text as evidence to support claims	benefits. These benefits might include: 1. Scientists engage in this practice, which includes: o Persuading one another o Developing new knowledge o Changing claims when new evidence is presented o Making informed decisions about claims using evidence 2. In science: o Science is messy, and there isn’t necessarily one “right answer” o Multiple claims are authentic to science o Science often involves disagreement 3. Allows students to engage in student-to-student discourse o A topic with multiple claims allows students to question and critique each other’s ideas 4. Students persuading and questioning one another o Change or question their own claims o That there are multiple sides to an argument and that it is important to see which provides the best	These benefits might include: 1. Scientists engage in this practice, which includes: o Persuading one another o Developing new knowledge o Changing claims when new evidence is presented o Making informed decisions about claims using evidence 1. In science: o Science is messy, and there isn’t necessarily one “right answer” o Multiple claims are authentic to science o Science often involves disagreement 2. Allows students to engage in student-to-student discourse o A topic with multiple claims allows students to question and critique each other’s ideas 3. Students persuading and questioning one another o May lead students to change or question their own claims o That there are multiple sides to an argument and that it is important to see which provides the best evidence o It is important to

		evidence o It is important to consider alternative or multiple claims or another points of view o Willingness to change ideas with the arrival of new evidence 5. Students becoming more critical consumers of science 6. Students develop a deeper understanding of the content 7. Prompts students to construct their own knowledge	consider alternative or multiple claims or another points of view o Willingness to change ideas with the arrival of new evidence 4. Students becoming more critical consumers of science 5. Students develop a deeper understanding of the content 6. Prompts students to construct their own knowledge
Drawbacks	Leader states that there could be inappropriate drawbacks such as: • Confusing students. This might look like: o The evidence is too confusing o Students with poor understanding of the content will become even more confused o The complexity of multiple claims is too confusing • There is no clear correct answer • It is too difficult to discuss different science concepts at once (e.g. animal and plant characteristics) • It takes too much time to consider multiple claims • Students may draw "incorrect"	Leader does not address drawbacks OR Leader states a vague drawback (e.g. debate styles missing)	Leader states there are no drawbacks

	conclusions, develop misconceptions, and/or share “flawed” or “incorrect” evidence or reasoning • This is too difficult for some or all students (e.g. ELL, Sped, struggling readers, etc.) • Students might get off track OR be distracted, and worry more about being “right” than the argument itself • More complicated than dealing with one claim	

Coding Scheme 3 (Ms. Strong)

Question: What are the strengths and weaknesses of how Alicia explains why her evidence supports her claim? Why?

Category	Level 0	Level 1	Level 2
Strengths of reasoning *Note: Leaders might talk about “strengths” using terms such as: does a good job, is great at, does includes, etc.	The leader does not address this topic OR The leader provides a strength that is inappropriate (e.g. Alicia includes multiple pieces of evidence) OR The teacher provides a strength that is inaccurate (e.g. Alicia includes science concepts to explain her	The leader provides a combination of strengths that are both appropriate and inappropriate. For example, this will often occur when leaders discuss some reasoning, but also talk about Alicia’s evidence e.g. Alicia provides multiple pieces of evidence to support her claim and describes why her evidence supports her claim e.g. Alicia uses the claim-evidence-reasoning format/framework/elements Note: Referencing evidence bumps code down to this level Also bump down if say addressing cost or	The leader states **one or more** strengths in Alicia’s reasoning. Leaders <u>do not</u> state any inappropriate strengths to receive this code. Strength could include: Alicia includes some reasoning Alicia describes why her evidence supports her claim. It is not enough to say she is connecting the evidence to knowledge or

	data)	convenience as a strength	ideas. Leaders might also talk about the reasoning in terms of the specific science content. For example: Alicia provides an explanation for how the special clothes she heard about on the Discovery Channel relates to her claim about human survival
Weaknesses of Reasoning *Note: Leaders might talk about weaknesses using terms such as: missing, lacking, does not have, etc.	The leader does not address this topic OR The leader provides a weakness that is inappropriate (e.g. Alicia does not provide enough evidence) OR If the language leaders use in their response is vague (e.g. Alicia's argument doesn't…) then code here	The leader provides a combination of weaknesses that are both appropriate and inappropriate e.g. Alicia does not describe how her evidence supports her claim (i.e. does not include reasoning), and she needs to incorporate a scientific principle to make clearer the connection between her evidence and claim Note: Referencing evidence bumps code down to this level If the language teachers use in their response is vague (e.g. Alicia's argument doesn't…) then do not code	The leader states **one or more** weaknesses in Alicia's reasoning. Leaders do not state any inappropriate weaknesses to receive this code. Weaknesses could include: The reasoning that Alicia includes is weak and/or non-scientific. Need to be specific about this reasoning not supporting the claim – not enough to say she states her opinion. Alicia does not include nor describe a scientific concept or principle that would explain the connection between her claim and evidence She does not explain why the chart showing that

			Mars gets much colder than Earth is important for human survival The connection or explanation that Alicia provides would not support a claim about survival, but instead about costs and convenience
Rationale	The leader does not address this topic OR The leader provides a rationale that is inappropriate for this question OR The leader discusses a big idea about argumentation that has nothing do to with the response to this question. (e.g. it's important for students to speak to each other, and not to the teacher)	The leader states a rationale that supports **either** the strengths or the weaknesses in the argument. This rationale could include: Reasoning makes an argument more convincing or persuasive It is important to include scientific concepts in an argument as a part of the reasoning (i.e. the content) It is important to explain why the evidence supports the claim (i.e the connection) NOTE: Code if they mention persuasion and/or either content or connection	The leader states **two different** rationales, each supporting either the strengths or the weaknesses in the argument. These rationales include: It is important to include scientific concepts in an argument as a part of the reasoning (i.e. the content) – addresses weakness It is important to explain why the evidence supports the claim (i.e the connection)— addresses strength NOTE: Code if they mention content AND connection

Coding Scheme 4 (Ms. Alves)

Question: What are the strengths and the weaknesses of the evidence Sofia uses in her argument? Explain.

Category	Level 0	Level 1	Level 2
Strengths	The leader does not address this topic OR	The leader provides a combination of strengths that are both appropriate	The leader states **one or more** strengths in Sofia's evidence. Leaders should

of Evidence *Note: Leaders might talk about "strengths" using terms such as: does a good job, is great at, does includes, etc.	The leader provides a strength that is inappropriate (e.g. Sofia includes good reasoning, OR Sofia's claim is accurate)	and inappropriate. e.g. Sofia identifies the landmasses' shapes as evidence, and explains how it connects to her claim Note: Referencing other structural aspects of an argument (i.e. claim and reasoning) bumps code down to this level Note: referencing Pangaea (or the reading around this concept) counts as a science idea (i.e. reasoning) and would bump it down.	not state any inappropriate strengths to receive this code. Must specify the evidence – it is not enough to say that she supported her claim with evidence from the diagram. Strengths could include: She identifies the shape of the landmasses as fitting together. The evidence Sofia provides is consistent with (or relevant to) her claim
Weaknesses of Evidence *Note: Teachers might talk about weaknesses using terms such as: missing, lacking, does not have, etc.	The leader does not address this topic OR The leader provides a weakness that is inappropriate (Sofia only includes evidence from the map, OR Sofia's response doesn't align with the guiding question, OR Sofia's argument gets off track)	The leader provides a combination of weaknesses that are both appropriate and inappropriate. e.g. Sofia does not include evidence, and there were many pieces of evidence that she should have included (e.g. rock type, fossil type) Note: Referencing other structural aspects of an argument (i.e. claim and reasoning) bumps code down to this level Note: referencing Pangaea counts as a science idea (i.e. reasoning) and would bump it down.	The leader states **one or more** weaknesses in Sofia's evidence. Teachers should not state any inappropriate weaknesses to receive this code. Weaknesses could include: She only uses one piece of evidence, or does not provide enough support. There were other pieces of evidence that she should have included (e.g. rock type, fossil type) Must specify the evidence – it is not enough to say that she should have supported her claim with more evidence from the diagram.
	The leader does not address this topic OR The leader provides a	The leader states a rationale that supports **either** the strengths or the weaknesses in the argument. This rationale	The leader states **two different** rationales, each supporting either the strengths or the weaknesses in the argument. These

Rationale	rationale that is inappropriate for this question OR The leader discusses a big idea about argumentation that has nothing do to with the response to this question. (e.g. it’s important for students to speak to each other, and not to the teacher)	could include: High quality evidence includes measurements and observations, not personal anecdotes or opinions (strength) High quality evidence makes an argument more convincing/persuasive (strength) The more evidence in support of a claim the stronger the argument (weakness)	rationales could include: High quality evidence includes measurements and observations, not personal anecdotes or opinions (strength) High quality evidence makes an argument more convincing/persuasive (strength) The more evidence in support of a claim the stronger the argument (weakness)