Principals' views of "good" science instruction:
Focused on general pedagogy, hands-on and investigations

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Principals' views of "good" science instruction: Focused on general pedagogy, hands-on and investigations

Recent reform efforts, such as the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), aim to shift the goals of science education. While traditionally science instruction has focused on content and science process skills separately (Bybee, 2014), contemporary views of science literacy stress the importance of knowledge in use. This means that students engage in authentic science practices to apply science concepts in diverse contexts to make sense of phenomena and to inform decisions (Duschl, Schweingruber & Shouse, 2007). Such goals necessitate that instructional leaders support teachers to change their instructional goals and pedagogy (Reiser, 2013; NRC, 2015; Krajcik et al., 2014). School principals will likely play a key role in such reforms, as they are typically responsible for supervision activities aimed at impacting teachers' classroom practice (Camburn et al., 2003; NRC, 2015). As such, principals' abilities to "notice" (Sherin & Van Es, 2005) and provide feedback about instruction will be essential to improving teachers' instruction (Stein & Nelson, 2003). However, little is currently known about how principals conceptualize effective science instruction. Therefore, in this study we investigate the following research questions: (1) How do k-8 principals describe good science instruction? (2) What do k-8 principals "notice" when watching videos of science instruction?

Theoretical Framework

Science Practices

Reform efforts such as the NGSS set forth a new vision of science education that prioritizes engaging students in the practices of science (NGSS Lead States, 2013). This view of science as a set of practices stems from the idea that scientists participate in a variety of activities that include specialized ways of reasoning, talking and writing (Lehrer & Schauble, 2006). Scientists utilize these practices as they enact the core work of science, which focuses on developing evidence-based explanations of how and why the natural world works (Windschitl, Thompson, & Braaten, 2008). As such, in the science classroom students construct and apply knowledge (Berland et al., in press) by building explanations of phenomena and developing explanatory models (Krajcik, et al., 2014).

This focus on practices is aimed to be substantially different than previous efforts to engage students in "inquiry" science. Inquiry became a ubiquitous term (Anderson, 2002) and such instruction in the classroom rarely involved students in the construction and critique of knowledge (Pruitt, 2014). Most state standards presented inquiry skills as separate from science content, leading students to enact some activities of scientists, such as conducting investigations, but rarely using these practices as a way to explore and explain the natural world (Pruitt, 2014). For this reason, the NGSS are written as performance expectations that integrate disciplinary core ideas (DCIs) with key science practices (Krajcik et al., 2014).

The NGSS include eight science practices (NGSS Lead States, 2013) that encompass the range of activities, discourses, and critical thinking typical of scientists (NRC, 2012). While each practice has its unique features, we believe that it can be useful to consider these practices in three groups: investigating practices, sensemaking practices, and critiquing practices (McNeill, Katsh-Singer & Pelletier, 2015) (Figure 1).

Investigating Practices	Sensemaking 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 1: Three Categories of NGSS Science Practices

We developed this grouping of the eight practices for two reasons. First, they are aligned with the overarching goal of science – to make sense of the natural world (Osborne, 2010; Russ, 2014). Second, while previous views of science as inquiry often focused on the investigating elements of science (Reiser, 2013), this grouping highlights the more challenging practices most often absent from k-12 instruction, the sensemaking (Berland et al., in press) and critiquing (Osborne, 2010; Henderson, 2015) practices. The first group, investigating practices, include those practices that engage students in asking questions and implementing methods of data collection (Duschl & Bybee, 2014). The second group, sensemaking practices, are those in which students analyze data and design representations based on that data to explain how and why phenomena occur, such as constructing models (Passmore & Svoboda, 2012). Finally, the third group, critiquing practices, focus on students evaluating different claims, representations and texts (Henderson et al., 2015) (Figure 1).

While all the practices have unique aspects, there are features of instruction and classroom culture that cut across all the practices. A focus on evidence is one such feature, as all the practices engage students in gathering, analyzing, or critiquing evidence. NGSS also prioritizes students collaborating with peers and directing some of their own learning, instead of the teacher presenting information to students (Reiser, 2013). In addition, there is an emphasis across the practices on students engaging in discourse with each other to construct and critique knowledge (NRC, 2012).

Teachers and the science practices. The focus on science practices provides a vision for teaching and learning that cannot be realized without sufficient support for teachers (NRC, 2012; Reiser, 2013: Passmore & Svoboda, 2012). However, research suggests that currently schools and districts are not prepared for the instructional reforms necessary to achieve the goals of the NGSS (Banilower et al., 2013). At the elementary level, teachers often hold views in stark contrast to the theory of learning advocated by the incorporation of science practices in the NGSS (Trygstad et al., 2013). For example, elementary teachers can believe that students should participate in hands-on activities after they have learned important content (Trygstad et al., 2013) instead of students utilizing the science practices to learn key ideas (NRC, 2012). In our own work we have found that teachers can be concerned that they are unable to simultaneously support students' learning of a scientific practice and their learning of science content (McNeill, Gonzalez-Howard, Katsh-Singer, Price & Loper, 2013; McNeill & Knight, 2013). Teachers may not have an integrated view of the science practices, in that the successful performance of a scientific practice requires the use and promotes deeper understanding of DCIs.

Teachers' views of good science instruction can also be quite different than a classroom culture that prioritizes science practices. For example, teachers can see science literacy as focused on final form science consisting of discrete concepts, facts and laws (Duschl, 1990). In addition, discourse in science classrooms is frequently teacher-centered and focused on the dissemination or presentation of discrete knowledge (Lemke, 1990). Science teachers in the United States often present science content as disconnected facts, definitions or algorithms rather than engaging students in the practice of science to develop their understandings of core science ideas (Roth & Garnier, 2006). Teachers can feel that they need to prioritize science content because it has traditionally been the focus in state standards and assessments (Pimentel & McNeill, 2013).

Besides a focus on the presentation of content, teachers can have other different views of good science instruction such as a focus on hands-on activities or the scientific method. For example, teachers can engage students in a lesson utilizing the scientific method such as investigating the effects of rock music or a soft drink on plant growth without an underlying model to help students understand the phenomenon (Windschitl et al., 2008). Although such activities may be engaging to students, they do not support students' use of the science practices to grapple with complex scientific ideas. At the elementary level, teachers can be more focused on science instruction that is dominated by hands-on fun activities, rather than engaging students in the sensemaking aspects of science practices that include disciplinary core ideas (DCIs) (Zembal-Saul, 2009).

Principals and Science Instruction

Given the substantial reforms necessary to shift science instruction to a focus on science practices, it is essential for teachers to receive sufficient support to develop an understanding of the science practices and appropriate instructional strategies that align with these goals (NRC, 2012; Reiser, 2013). In their roles as instructional leaders, principals are positioned to be tremendously influential in this regard.

The role of principals. In recent years, the job responsibilities of principals have increased substantially in number and complexity (Fullan, 2007; Leithwood, 2001). Principals must still attend to the unique needs of the constituents and contexts in which they work (Lowenhaupt, 2014; Zepeda, 2012; Hallinger, 2005), and perform a myriad of administrative and managerial tasks to ensure the smooth running of their schools (Copland, 2001). However, accountability policies now also strongly influence the work of principals (Ladd & Zelli, 2002; Lowenhaupt, Spillane, & Hallett, in press). Such policies typically frame principals as instructional leaders who are responsible for guiding teachers to improve classroom instruction and test scores.

One way principals enact instructional leadership is by using evaluation systems to impact teacher learning, improve classroom instruction, and increase student achievement (Leithwood et al., 2004; Marzano, Waters & McNulty, 2005). This most often includes observing classroom instruction and providing feedback to teachers (Marshall, 2009). Principals typically supervise teachers across subject areas (Sergiovanni et al., 2013), and many observation protocols focus on general pedagogical features such as student engagement (e.g. Danielson, 2002). However, recent reforms aimed at improving students' learning of specific content, such as the Common Core and the NGSS, necessitate that principals provide feedback tailored to individual disciplines (Hill & Grossman, 2013). As such, principals' understanding of the subject is key to the ways in which they exercise instructional leadership and supervision in the content areas (Nelson & Sassi, 2005; Spillane, 2005). This raises the question of what principals understand to be high quality science instruction, particularly in relation to recent reform efforts. As such, in this study we investigate principals' conceptions of "good" science instruction.

Noticing. In addition to the ways principals understand effective science instruction, we are interested in what they "notice" about science instruction in k-8 classrooms. "Noticing" is focused on what individuals do and do not attend to when observing classroom instruction, and how they actively interpret this activity (Sherin, Jacobs, and Philip, 2011). For principals who conduct observations and provide feedback as part of their instructional leadership of teachers (Marshall, 2009), their ability to notice and interpret (Sherin & van Es, 2005) elements of practice-based science instruction is essential. Leaders must understand teachers' possible conceptions about instructing the practices, effectively facilitate conversations with teachers about such conceptions (Kazemi et al., 2011), and provide feedback (Bambrick-Santoyo, 2012) that supports teachers at continually improving their instruction of the science practices. Therefore, in this study we investigate what principals notice about classrooms engaged in science instruction.

Methods

Participants

In this study, we interviewed twenty-six current k-8 principals about science instruction and science supervision. During the 2014-2015 school year, we purposefully recruited principals from six different school districts near a large urban area in the Northeast of the USA. We selected the districts based on the percentage of students passing the state science test, identified as low income and identified as English Language Learners (ELLs). Our goal was to include districts above and below the state averages for these characteristics (Table 1).

Table 1: District Demographics.

District	Number of Principals Interviewed (n = 26)	Enrollment	Number of Schools	Locale[1]	% Gr. 5 Students Scoring A or P[2]	% Students Identified as Low Income	% Students Identified as ELLs
Oak Park	2	5,368	8	Suburb: Large	89%	9.6%	1.0%
Ogden	7	12,674	22	City: Small	89%	11.4%	7.2%
Clinton	2	7,508	12	Suburb: Large	87%	11.4%	9.0%
Greenville	4	8,153	14	City: Small	85%	39.7%	13.4%
Troy	3	4,987	11	Suburb: Large	67%	66.9%	16.8%
Chester	8	54,312	120	City: Large	47%	77.7%	29.9%
State Average		---	---	---	71%	38.3%	7.9%

[1]Locale determined from the National Center for Educational Statistics.

[2] A = Advanced and P = Proficient on 2014 Science State Test

For each of the targeted districts, we e-mailed principals directly describing the study and asked if they would be willing to be interviewed. Upon completion of the interview, principals received a $75 Amazon gift card. We originally intended to accept the first twenty-five principals who expressed interest in the study. However, we received interest from the final two respondents simultaneously so we decided to include both of them in the study resulting in twenty-six final participants.

The twenty-six participants included sixteen females and ten males. In terms of race, they identified as the following: nineteen as white, four as Black or African American, and three as Hispanic or Latino. In terms of previous school experience, the participants ranged from 2-5 years to over twenty years as a principal and from 0 to over twenty years as a teacher (Table 2). Interestingly, only three of the participants were certified in science, all of whom were former middle school science teachers.

Table 2: Principal Information

ID	Grades	District	Years Admin	Years Teaching	Teaching License
08	Elementary	Oak Park	6-10	2-5	Elementary
10	Elementary	Oak Park	6-10	11-15	Elementary & SpEd
12	Elementary	Ogden	6-10	>20	Elementary
13	Middle	Ogden	6-10	11-15	Social Studies & ESL
14	Elementary	Ogden	2-5	6-10	Elementary
15	Elementary	Ogden	6-10	2-5	Social Studies & Guidance
16	Elementary	Ogden	6-10	> 20	Elementary & SpEd
18	Elementary	Ogden	> 20	11-15	Elementary & Literacy
19	Elementary	Ogden	6-10	11-15	Elementary & Science
05	K-8	Clinton	2-5	6-10	Elementary
20	K-8	Clinton	16-20	0	Guidance
03	Elementary	Greenville	11-15	> 20	Social Studies
06	Elementary	Greenville	11-15	11-15	Early Childhood
07	Elementary	Greenville	11-15	6-10	Elementary
09	Elementary	Greenville	> 20	2-5	Elementary & Bilingual
01	K-8	Troy	6-10	6-10	English Language Arts
02	K-8	Troy	16-20	11-15	Elementary
11	K-8	Troy	6-10	1	Elementary
22	K-8	Chester	11-15	2-5	Elementary & SpEd
23	K-8	Chester	11-15	11-15	Science
24	K-8	Chester	2-5	2-5	History
25	K-8	Chester	6-10	> 20	Science & Math
27	Middle	Chester	2-5	6-10	English Language Arts
28	K-8	Chester	2-5	0	English as Second Language
30	Middle	Chester	11-15	6-10	ELA & Social Studies
31	Elementary	Chester	6-10	6019	Elementary

Data Collection

This study examined one data source: interviews with 26 k-8 science principals. Each principal was interviewed for approximately 40-60 minutes using a semi-structured interview protocol. Because of the exploratory nature of this study, the goal of the interview protocol was to encourage a discussion with the principal, which allowed the participant's perspective to unfold and not be biased by the interviewer (Marshall & Rossman, 1999). The interview focused on four different sections: general supervision, science instruction, science supervision and video analysis. The first three sections consisted of open-ended questions such as – "What do you see as the primary goals of supervision?", "What do you think good science instruction looks like?" and "Describe what science supervision is like in your school." After the initial questions, if the principal mentioned something that was unclear, the interviewer would follow-up with a probe such as "You mentioned_________. Can you tell me more about that?"

In the last section of the interview, each principal was shown two video clips from k-8 science instruction, each of which lasted approximately 2 minutes. After observing each video, the principals were asked questions such as "What do you notice about the science instruction?" and "How would you follow up with this teacher?" Similar to the first three sections of the interview, if the principal said something unclear or vague, the interviewer followed with probing questions. All of the interviews were recorded and transcribed for analysis.

Data Analysis

Codes for "good" science instruction. In this paper, we focus specifically on principals' views of "good" science instruction. We were interested both in how the participants described good instruction broadly during the first three sections of the interview, as well as what they "noticed" as good instruction when observing the two videos of classroom instruction. The coding scheme was developed from both our theoretical framework and an iterative analysis of the data (Miles & Huberman, 1994). Our research stemmed from our interest in understanding principals' current views about science instruction in order to better support their development of a richer understanding of the eight science practices in NGSS. Consequently, we wanted a subset of the codes to align specifically with the research and goals around the science practices (Berland et al., in press; Osborne, 2014). One challenge in coding for the science practices is that the eight practices are not distinct, but rather overlap and work synergistically in important ways (Bell, Bricker, Tzou, Lee & Van Horne, 2012). Consequently, instead of coding for each individual science practice, we decided to group the practices.

As discussed previously, we developed three groups for the science practices– investigating, sensemaking and critiquing (McNeill et al., 2015) (See Table 3). We were interested in whether or not principals would be more likely to discuss the investigating practices compared to the sensemaking and critiquing practices since sensemaking (Berland et al, in press) and critiquing (Henderson et al., 2015) have been more frequently left out of previous science reform efforts.

Table 3: Codes for Science Practices – Investigating, Sensemaking and Critiquing

Code	Description
Investigating Practices	• Discusses at least one of the 3 Investigating Practices as important for good science instruction: Asking questions, Planning and carrying out

	investigations or Using mathematical and computational thinking • This can include targeting the practices with different language such as collecting data or conducting experiments or observing phenomena
Sensemaking Practices	• Discusses at least one of the 3 Sensemaking practice as important for good science instruction: Developing and using models, Analyzing and interpreting data or Constructing explanations • This can include targeting the practices with different language such as explaining how or why a phenomena occurs
Critiquing Practices	• Discusses at least one of the 2 Critiquing Practices as important for good science instruction: Engaging in argument from evidence or Evaluating information • This can include targeting the practices with different language such as critiquing competing scientific claims or students questioning and evaluating each other's ideas.

In addition, we developed other codes for the principals' descriptions of "good" science instruction (See Table 4). Some of the codes stemmed from previous research focused on the science practices (Berland et al., in press; Osborne, 2014) and common challenges with science instruction such as focusing on presenting discrete facts to students (Pimentel & McNeill, 2013; Roth & Garnier, 2006). Other codes stemmed from our initial read through the interviews looking for emergent codes grounded in the principals' own language (Strauss, 1987). For example, we found it interesting that when talking about good science instruction that some principals did not see it as distinct from other disciplines. For example, Principal 12 commented "it doesn't matter what content you're teaching" (see Table 4). Therefore, we developed the "good teaching" code.

Table 4: Codes for "Good" Science Instruction

Code	**Description**
Natural World	Talks about science focusing on making sense of the natural world or nature or the world around us.
Evidence	Discusses the importance of students collecting and/or using evidence or data in science instruction.
Student-directed	Talks about the importance of students leading or taking charge of their science experiences. Students should run discussions, investigations, etc.
Collaborative	Talks about students working in groups or working together during good science instruction
Language rich	Discusses how language is an important part of science instruction, such as the importance of engaging students in science talk.
Inquiry	Discusses "inquiry" or "scientific inquiry" as important for science instruction.

Hands-on	Talks about the importance of students' science being hands-on or kids doing science.
Scientific Method	Uses the phrase the "scientific method" as being an important part of science instruction.
Presenting	Talks about the importance of the teacher, a video or a textbook presenting the science concepts. This is focused on transmission or dissemination of science content.
Good Teaching	Discusses how good science teaching is just like good teaching in other disciplines.
Other Disciplines	Talks about good science instruction as supporting learning of literacy/ELA or math. The goal of the instruction is not the science, but rather these other disciplines.
Science Content	Evaluation or Feedback about science content in terms of either genetics (Video 1) or sound (Video 2) illustrating an understanding of the science content.
Pedagogy	Evaluation or feedback about general pedagogy strategies such as – arrangement, activity structure, using a visual, using an essential question – that are not specific to the science content.
Student Engagement	Evaluation or feedback about student engagement such as discussing that students are or are not engaged, focused or interested in the science lesson.

A specific quote could be coded for more than one of the codes in Tables 3 and 4. For example, if a principal said - students should engage in inquiry where they are conducting actual experiments in the classroom and collecting evidence - the quote would be coded for "Investigating Practices" (Table 3), "Evidence" (Table 4) and "Inquiry" (Table 4). We did not see these codes as mutually exclusive, but rather we wanted to use them to characterize all aspects of how the principals talked about "good" science instruction.

Codes for "noticing" of video examples. In addition to the general science instruction codes, we developed codes for the video section of the interview (Table 5). Again, these codes were developed through an iterative process (Miles & Huberman, 1994) using both the research literature, such as previous literature suggesting principals' evaluation often focuses on general pedagogy and engagement (Danielson, 2002), and the principals' own language (Strauss, 1987). Three codes about science instruction were added to this section – content specific, pedagogy and student engagement. The goal of these codes was to capture whether the principal was specifically providing feedback on the science content (i.e. science content) or talking more broadly about the pedagogy or student engagement that was devoid of specifics about science content or the science practices (i.e. pedagogy and student engagement).

Table 5: Additional Codes for Science Instruction for Principals' Noticing of the Videos

Code	Description
Science Content	Evaluation or Feedback about science content in terms of either genetics (Video 1) or sound (Video 2) illustrating an understanding of the science content.

Pedagogy	Evaluation or feedback about general pedagogy strategies such as – arrangement, activity structure, using a visual, using an essential question – that are not specific to the science content.
Student Engagement	Evaluation or feedback about student engagement such as discussing that students are or are not engaged, focused or interested in the science lesson.

We also specifically chose the videos so that one aligned with the science practices perspective (Video #1) and the other did not align (Video #2). We were interested in whether the principals were more likely to discuss Video #1 or Video #2 in a positive light. Video #1 was from a science seminar in a middle school classroom in which the students were engaged in argumentation about what kind of allele causes the glowing trait in cats (See argumentationtoolkit.org). The cats were genetically engineered using genes from glowing jellyfish. During the video, students are sitting in a circle debating whether the allele for fluorescence is dominant, non-dominant, or incompletely dominant. They are using data from genetic crosses of both the original jellyfish and the cats. During the video, the teacher only speaks once towards the beginning where he asks, "The next piece of evidence that we might want to discuss - Remember Study 2 about those jellyfish that had all the kids. I am wondering what people thought about that, what kind of sense can we make of that?"

The second video was from a 2nd grade classroom beginning a unit on sound. During this video, the classroom discussion is dominated by teacher talk and does not focus on the science practices. The teacher is standing in front of the room by a white board and the students are sitting on the rug at her feet. She begins by introducing the essential question, which is written on the board, "How do we hear sounds?". She then tells the class, " I am going to tell you that sound travels in waves (hand gesture making a wave)." She then goes on to explain, "That part of your ear is called the outer ear and the reason it is shaped like that is because it is trying to catch the waves (hand gesture making a wave). On the board, she draws a picture with waves, the outer and inner ear labeling the ear canal and ear drum. The only student voice during the video is after she draws her picture a student says, "That is good.".

Table 6: Evaluation Codes for Principals' Noticing of the Videos

Code	Description
Positive Evaluation	Across the discussion of video 1 or video 2, the principal is overall more positive in their evaluation. Receives one code per video.
Neutral Evaluation	Across the discussion of video 1 or video 2, the principal is either 1) Mainly descriptive and does not evaluate or 2) Provides an even mixture of positive and negative comments. Receives one code per video.
Negative Evaluation	Across the discussion of video 1 or video 2, the principal is overall more negative in their evaluation. Receives one code per video.

Reliability. The transcripts and coding schemes were uploaded into NVivo qualitative data analysis software for data coding and analysis. Two independent raters coded the transcripts. One initial interview was selected for coding. We then used the NVivo node reports to refine and clarify the coding scheme. A second interview was selected for an additional round of revision resulting in the final coding schemes (see Tables 3 and 4). We then randomly selected

20% of the remaining transcripts (i.e. 5 interviews) and two raters independently coded each transcript. We calculated Cohen's kappa to determine the inter-rater reliability. Landis and Koch (1977) provide guidelines for kappas between 0.21-0.40 as fair, 0.41-0.60 as moderate, 0.61-0.80 as substantial and 0.81-1 as almost perfect agreement. Our Cohen's Kappa score for the two independent raters was 0.73 suggesting substantial reliability. All disagreements were resolved through discussion to determine the final codes.

Data Reduction. After coding the data, we then used NVivo to generate matrix coding tables and to run coding queries. We used the tables and developed graphs to facilitate the process of looking for patterns (Miles & Huberman, 1994) in the principals' responses to both their general descriptions of good science instruction and specifically for what they "noticed" when watching videos of science instructions. This process resulted in four initial themes. To challenge and refine these themes, we looked for confirming and disconfirming evidence across the interviews resulting in revision of the themes (Erickson, 1986). In the presentation of these four themes, we selected quotes to illustrate the overarching patterns and to include a range of principals to highlight different voices.

Results

The results of our data analysis suggest four themes about how principals' view and notice 'good' science instruction (Table 7). The first two themes relate to the principals' descriptions of "good" science instruction in terms of how their descriptions aligned with the vision of the science practices as well as other characteristics that emerged from their own language. The second two themes focus on what principals notice when observing and evaluating video of science instruction. For each theme, we present data from the interviews to support and illustrate these ideas using the principals' own language.

Table 7: Principals' views and noticing of science instruction

Theme 1	Principals often described "good" science instruction as including the investigating practices, but rarely included the sensemaking or critiquing practices.
Theme 2	Almost all of the principals described "good" science instruction as being hands-on, though they had different meanings of what counted as hands-on.
Theme 3	In terms of "noticing", when principals observed videos they focused on general pedagogy and student engagement with few comments about the science practices or content.
Theme 4	In terms of evaluating, when principals critiqued videos the majority of their evaluations did not align with the quality of the science practices.

Theme 1: Principals often described "good" science instruction as including the investigating practices, but rarely included the sensemaking or critiquing practices.

We coded the principals' descriptions of good science instruction to see how closely they aligned with the science practices. Figure 2 shows the percentage of principals that discussed each of the three groups of practices – investigating, sensemaking and critiquing. The majority of principals (77%) did talk about Investigating Practices as being important for science classrooms. The Sensemaking Practices (38%) and Critiquing Practices (12%) were much less prevalent.

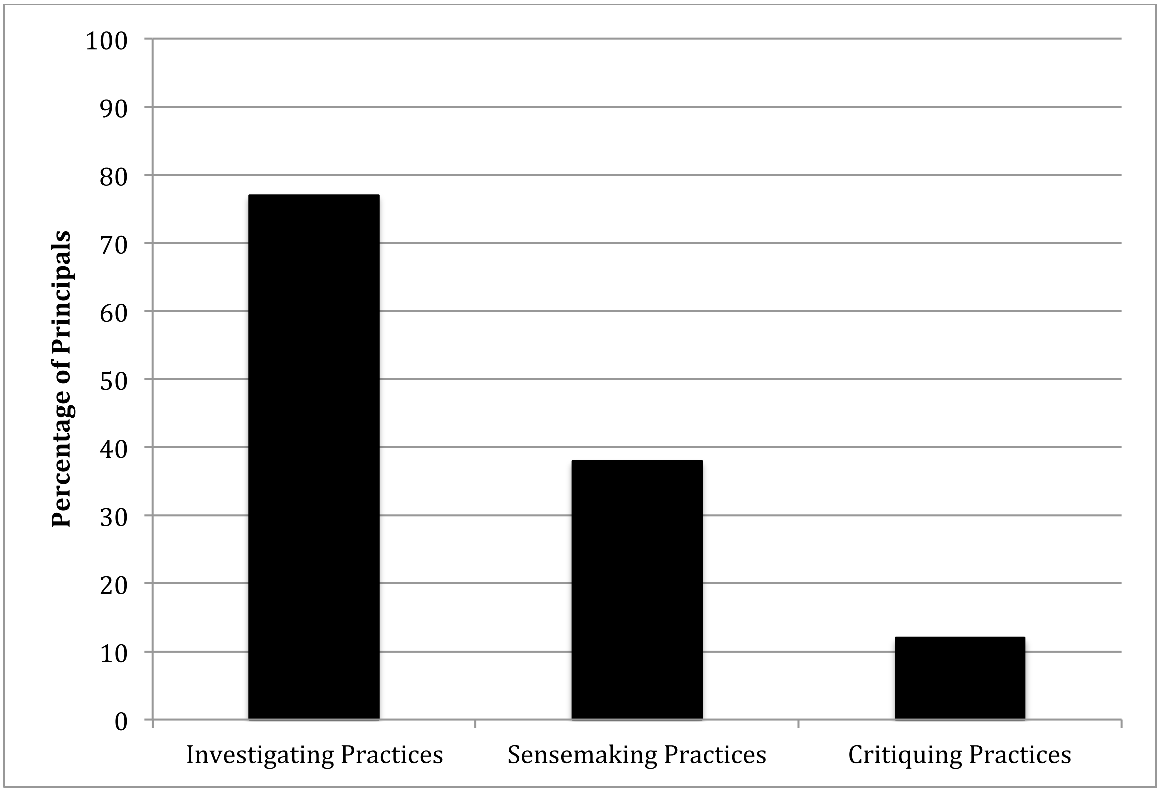

Figure 2: Descriptions of good science instruction in relation to the science practices

In describing good science instruction, most principals (77%) discussed the Investigating Practices, usually with general language about the importance of students doing labs or experiments in science. For example, Principal 2 stated, "When I visit my science teacher and he's doing the lab, the level of engagement, in my opinion, is much higher than when I go in and he's talking to them about stuff." Principal 27 discussed good science instruction as "I'd see them conducting an experiment or trying out a problem." Principal 16 discussed what she would like to see when she saw instruction in her elementary school. She stated

> *Kids need – they learn some content about science, but the act of science really is about manipulation and investigation. That's what I look for when I look at science. I honestly, don't see a lot of that. I've never seen a lot of that in my career with – as a principal.*

The interviews suggest that when the principals saw science instruction they were looking for it to include students engaged in investigations and experiments.

A smaller number of the principals (38%) brought up the sensemaking practices – that students should not just be doing experiments, but that they need to analyze data, construct explanations and develop models. Conducting an experiment is not the end goal, but rather students need to engage in making sense of those experiences. For example, Principal 5 talked about both the Investigating Practices and the Sensemaking Practices in conjunction with each other when describing good science instruction:

> *I think it looks like kids investigating questions and drawing conclusions by using data….really facilitating and helping kids grow those skills of investigation and basing your conclusions on data*

In this example, Principal 5 does not stop at conducting an experiment, but rather links this to students analyzing the data and making sense of it. In addition to analyzing data, other principals mentioned students develop explanations or models either using general language or specific examples. For example, in describing what students are doing during good science instruction Principal 25 stated, "They're posing explanations. They are having fun. They are making models." In contrast, Principal 8 used a specific example to illustrate that he thought good science instruction should focus on the curiosities and problems in the world to better understand, "Why does this happen?". Specifically, he discussed a plant example in which students could be answering "Why do you think it has big, broad green leaves like that?", which would enable students to address the question of why this specific phenomenon, big broad leaves, occurs.

In terms of Critiquing Practices, only three of the principals (12%) mentioned critique during their interview. For example, in describing what students would be doing during "good" science instruction, Principal 10 talked about the students building on and critiquing each other's ideas. Specifically, he said:

> *They would be talking with each other. They would be challenging each other. Not physical or – but saying, 'What do you think matters?" I'm not a huge science expert, so I don't want to give an answer that's way off and people are laughing when they listen to it (laughter). When they talk about the content, that they're saying, "It could be that, but how about this. Let's try these strategies. Let's build this.*

Principal 10 offers a vision of science in which students consider and evaluate different options. This reflects the ways in which he discussed his overarching goal for students, "I think the most important thing for them to learn in science is there's not one right answer." Interestingly, while he offers this vision that aligns with many aspects of the science practices, he also questions his ideas because he is "not a huge science expert". This is in contrast with Principal 19 who also discussed critique, but he relied on his experiences as a middle school science teacher. As mentioned previously, only three of the principals were certified in science. Of the three, Principal 19 was the only one to discuss the Critiquing Practices in his interview. Specifically, he said:

> *My job was to get kids excited about science. It wasn't to get them to memorize the periodic table or know which planet was necessarily the hottest. It was – Okay. Now that we've learned all about the planets, I want you to pick a place where you'd want to go. I want you to make an argument for whether you could live there or not.*

His vision of science was different than the majority of the participants. He discussed science as including the debate and critique of different ideas, not just running investigations or memorizing content. In fact, across his interview there were six different instances in which he brought up Critiquing Practices in response to a variety of questions, using language such as "defending your opinion", "design and redesign and tweak and evaluate…that experiment that you've designed", "debates about nature versus nurture" and "debate and engage in conversation on and defend their statements and sort of counter claims."

Across these three codes, principals often brought up the Investigating Practices in that students should be engaged in labs and experiments in their science classrooms. However, their descriptions often stopped there. Principals' descriptions often lacked the sensemaking aspects in which students construct explanations and models that focus on how and why phenomena occur. Principals were even less likely to discuss critique in which where students consider and evaluate multiple ideas and engage in argumentation to develop the strongest explanation or model.

Theme 2: Almost all of the principals described "good" science instruction as being hands-on, though they had different meanings of what counted as hands-on.

In addition to coding the principals' descriptions explicitly for the science practices, we coded the transcripts for other characteristics. Some of these aligned closely with the science practices, while others were quite different from the underlying goals of the new reform efforts. Figure 3 includes these codes with the left hand side including darker codes more closely associated with the science practices and the right hand side including lighter codes capturing different descriptions. For example, natural world (19%) and evidence (12%) are both dark, because they closely align with the underlying goals of the science practices in which students use evidence to make sense of the natural world. Good teaching (31%) and other disciplines (42%) are light, because in these descriptions principals either discussed that there was nothing unique about good instruction in science compared to other disciplines (i.e. good teaching) or they talked about the role of science instruction to be to support English Language Arts or Mathematics learning goals (i.e. other disciplines).

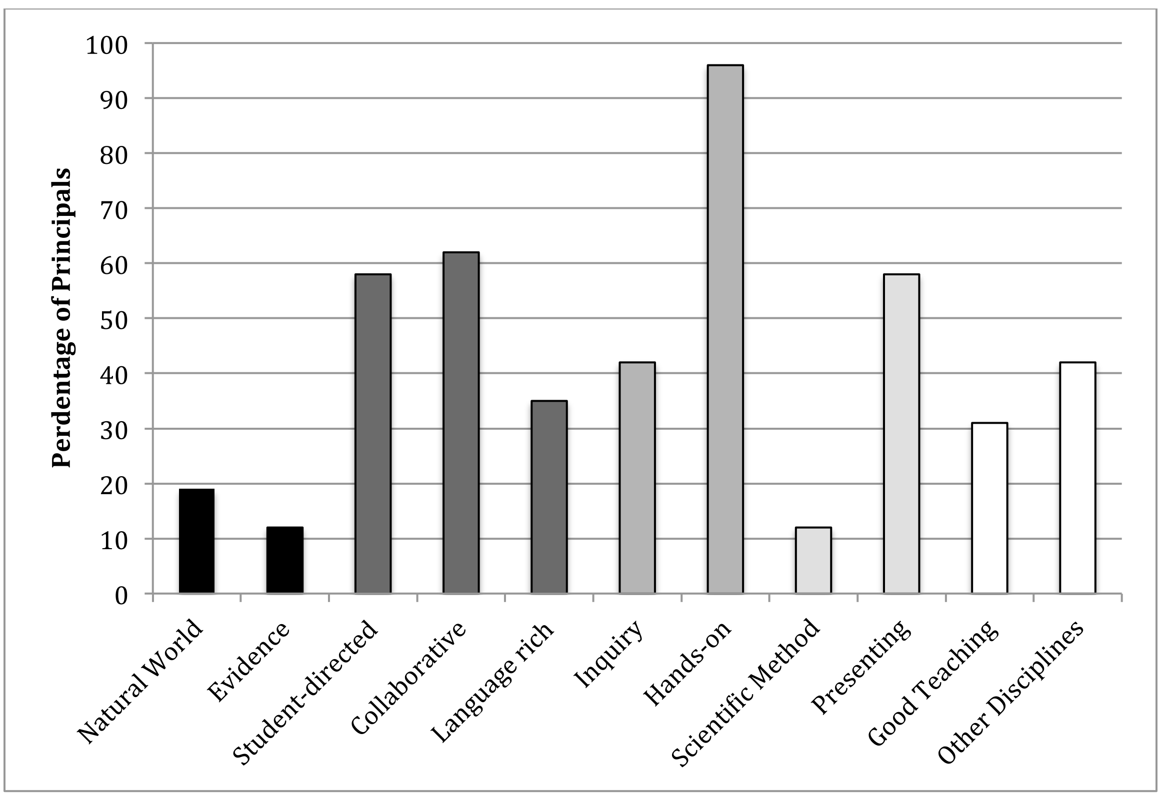

Figure 3: Description of "good science" instruction for different characteristics

Across the eleven codes, we see a spread in terms of which ideas the principals included in their descriptions of good science teaching. However, the most common code used to characterize the principals' description of good science instruction was "hands-on", which included all except one principal (96%). Many of the principals talked about hands-on as being a unique aspect of science instruction. For example, when discussing about good instruction, Principal 2 stated, "I think good science is hands-on. It shouldn't be that old-school version of a teacher standing up there, talking, talking, talking – the kids have to do hands-on things." Although hands-on was a common description of high quality science instruction, the principals appeared to have different understandings of what counted as hands-on activities in science.

For some principals, their descriptions of hands-on aligned with the Investigating Practices, while other principals provided different meanings or unclear meanings. In terms of Investigating Practices, as mentioned previously, 77% of the principals (Figure 2) received this code. For some of those principals, "hands-on" appeared to be another way to talk about students engaged in investigations or experiments. For example, Principal 14 discussed how students "should be able to do experiment and kind of get – put their hands on things." In a similar manner, Principal 11 talked about good science instruction as "doing experiments in the classroom, you know, if they're doing a lot of hands-on creative things." In a similar manner, Principal 5's description of good science instruction included both investigating and hands-on. She described it as:

> *I think it looks like kids investigating questions and drawing conclusions by using data, less teacher talk, lots of hands-on, lots of – primary source is more of a social studies word, but real tools and real – I don't know what the word is, real stuff [laughter] to look at in terms of the real organism or real whatever.*

In this description, Principal 5 struggled with some of the language to use for her description of good science instruction, but she connected it to "investigating questions and drawing conclusions by using data" and "real stuff." All of these principals' descriptions of good science instruction were coded as both "Investigating Practices" and "Hands on." Consequently, although the phrase "hands-on" can have a variety of meanings, for these principals the phrase depicted more of a focus on investigating and engaging with real phenomena.

However, there were a number of other principals that talked about the importance of hands-on experiences in science, but did not bring in the idea of investigations or experiments. For example, Principal 22's interview was not coded for Investigating Practices for any of the questions, but did include multiple instances in which she talked about "hands on." When describing good science instruction she said, "I think it looks different in science in that it should be much more hands on… Kids do something. They might be able to talk about it or do it." Although she used the language of hands-on and doing as being distinct in science, she was never explicit about what that exactly included. Principal 30 also offered a vague description of good science instruction and never mentioned the Investigating Practices stating, "It's a mix of pretty intensive science literacy combined with hands-on exploration." In a similar manner, Principal 25 received multiple codes for "Hands-on", but the interview was not coded for the Investigating Practices. When describing good science instruction, Principal 25 stated:

> *It is hands-on. It's constructivist. It has a strong – particularly here there's a strong literacy component so you're really teaching students the language of*

science…Being clear about what key ideas that they're supposed to be taking away from the class, key vocabulary that is part of that day's learning, but that they're making sure students all have an opportunity to interact, to do stuff. Also, ideally that they also are doing some writing every time they're in science class

In this case, Principal 25 connected hands-on to doing stuff, but also to writing and literacy strategies. Consequently, all three of these principals did not receive a code for "Investigating Practices", but did use the language of "hands-on," suggesting it had a different meaning.

Other principals received both the "hands-on" code and "Investigating Practices" code, but for different points during their interview. When they talked about "hands-on", it was unclear whether or not they connected this to the idea of investigating. For example, in describing what he looks for in a good science lesson Principal 3 said:

kids should be engaged in a science activity. It should be more activities and, like I mentioned earlier, experiential learning. Academic behaviors, writing, and responding to something in writing. All teaching should be – kids should be actively engaged and participating.

Although he talks about activities, there is no discussion of investigations, experiments or exploring a specific phenomenon. The description actually suggests that writing would could as "hands-on. Principal 31 also discussed good science instruction as hands-on, but did not talk about the Investigating Practices during this point of the interview. Specifically, she said

Well, it just like the workshop model where you might come in, you might do your mini lesson for no more than ten minutes. You may also include some of the mentor texts that gives them the strong content and background knowledge that they need, and the vocabulary or academic language. A huge bulk of time is spent on hands-on. While you're doing hands-on the teacher is circulating the room, interviewing kids and seeing where they are

In this example, the principal seems to map good science instruction onto an English Language Arts workshop model of instruction. Similar to some of the previous examples, there are connections to literacy, but here more so in terms of reading mentor text and vocabulary. Consequently, across the interviews hands-on was a common description of good science instruction. For some principals, this phrase appeared to align closely with the investigating aspects of the science practices, while in other instances the description was vague or appeared to be connected more to English Language Arts.

Theme 3: In terms of "noticing", when principals observed videos they focused on general pedagogy and student engagement with few comments about the science practices or content.

In the last part of the interview, we asked principals what they "noticed" in two short video clips and how they would follow-up with the teacher in terms of both questions and feedback. Figure 4 provides the frequency of codes for both videos. Similar to the previous figure, the left hand side of the figure aligns more closely with science practices and the right hand side of the figure includes other characteristics more removed from the science practices. However, in this case the colors in the figure are for the two videos. As described in the Methods, Video 1 (in black) focused on students engaged in argumentation aligning more closely with the science practices. Video 2 (in white) was primarily a teacher-directed lesson in which the teacher presented information about sound.

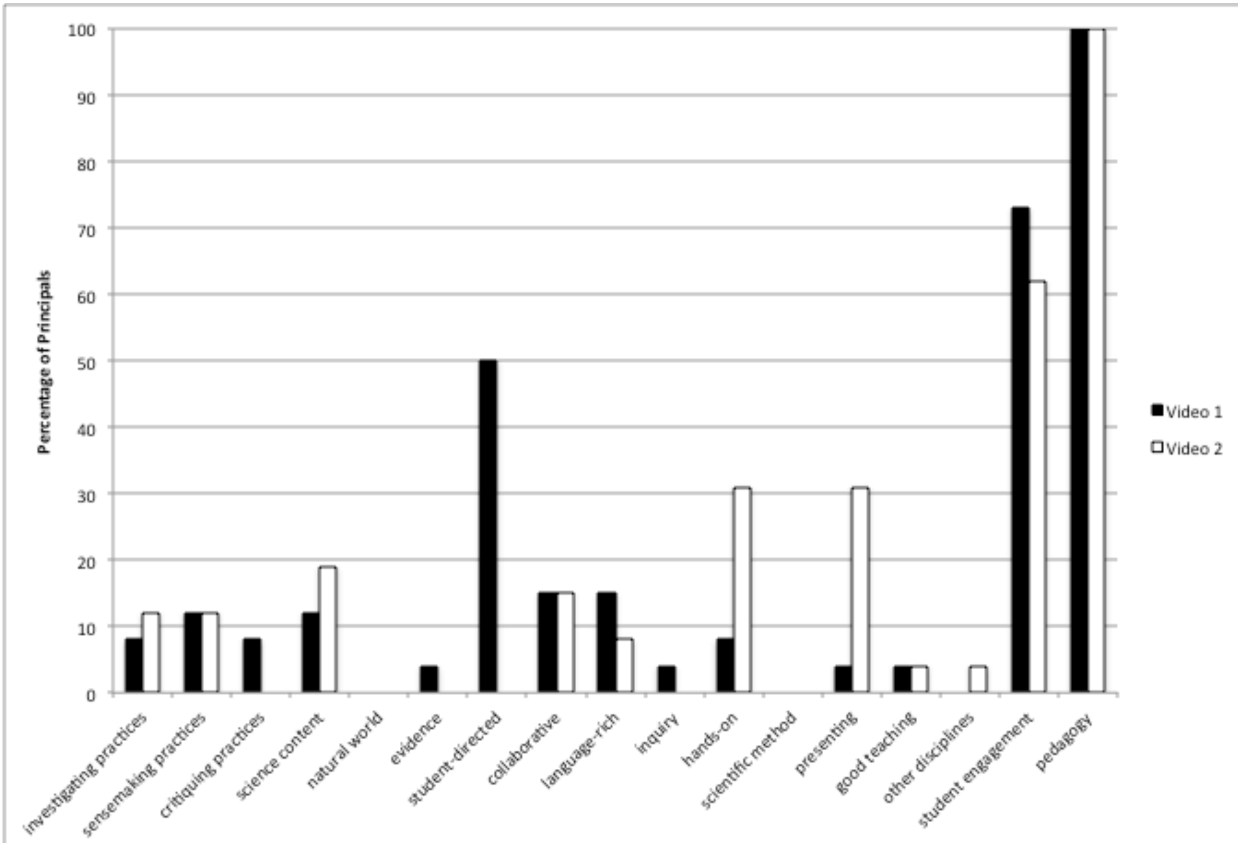

Figure 4 – Codes for Principals' Noticing and Feedback for Video Examples

By far the most common principal comments across both videos are reflected in the two codes on the far right of Figure 1, general "pedagogy" and "student engagement". These types of comments did not focus on the science ideas in the teacher talk, student talk, instructional activities or classroom representations, but rather focused on general aspects such as the configuration of the room, the gender of the students participating or the engagement level of the students. For example, Principal 13 critiqued Video 1 in which the students were engaged in argumentation offering general pedagogical strategies such as, "I think it might be helpful to have that question written out." Principal 24 offered a similar evaluation of the first video focused on the structure of the classroom activity.

> *The portion of the video, or the lesson that saw, seems very unstructured in the sense that I don't know what the students are working towards or anything like that. It just seems like they're sitting in a circle talking. Some are kind of tracking the speaker, and talking to each other, but there are some who are on their iPads in the background…I would categorize the short portion that I saw from the teacher is ineffective because it seems so unstructured.*

This principal also focused on the pedagogy, but critiqued the “unstructured” natural of the classroom perhaps because the student voices dominated the conversation. Principal 11 also provided a critique of Video #1, but focused more on student engagement:

> *I’m thinking a more effective approach to this would be, you know, put the kids in pairs or groups of three with separating those three students that seem to be the only ones answering and putting them into separate groups to really kind of help facilitate conversation*

This critique focused on the number of student voices heard during the approximately 2 minute video clip and not on the nature of what the students said. Consequently, this comment was coded as student engagement. Interestingly, across all three of these examples and many of the principals’ statements coded as pedagogy or engagement, the comments do not include any science specific comments. From these quotes, it is unclear whether the principal is observing a lesson focused on science, mathematics, social studies or English. Instead, the comments are very general in terms of both what the principals notice and provide feedback on.

Although it was rare, there were instances when the principals did talk more about the science. In terms of the science practices, these were rarely brought up by the principals with the Sensemaking Practices being the most common in both Video 1 and Video 2 at 12%. The comments on the science practices were more focused on the actual ideas being shared during the video examples. For example, we coded Principal 9’s feedback on what she saw as effective during Video #1 as sensemaking, because it focused on students analyzing and interpreting data

> *He was definitely allowing the students themselves to figure out, to try to grapple with the data and make sense of it. There’s benefit to that. I mean, they were obviously, at least those three students sounded like they knew what the data had showed them, and they were trying to figure it out.*

Although this principal did still comment on the number of students talking (coded as pedagogy), she also provided feedback on what the students were talking about. Her feedback suggests that she recognizes this as productive science talk in which students were able to “make sense” of the data they were discussing.

A couple of principals also focused on the Investigating Practices. For example, for Video 2 both Principal 16 and 18 discussed the lack of opportunities for students to investigate sound in their feedback for the teacher. For example, Principal 18 said, “so what are the experiments that get these kids moving and active? You don’t want them sitting for too long… I mean there are a lot of experiments she can do with sound.” Principal 16 raised a similar question asking, “How could they have experimented to really develop an understanding of why the ear is shaped in a certain way? Why animal ears are shaped in certain ways?” In both examples, the principals focused on the idea that students should be engaged in investigations rather than sitting and listening to the teacher present the science concepts. The principals are not providing science specific suggestions of what sound experiments to do. But this feedback is more focused on science in that they are looking for investigations – it is clear they are not observing an English Language Arts lesson. In the principals’ comments focused on the science practices, the observations and feedback move beyond just general pedagogy and student engagement to provide feedback that could help support a classroom culture prioritizing the science practices.

Theme 4: In terms of evaluating, when principals critiqued videos the majority of their evaluations did not align with the quality of the science practices.

In addition to the characteristics the principals considered when discussing the video, we were also interested if their comments provided a positive evaluation, negative evaluation or neutral evaluation of each video in relation to how closely the video aligned with the science practices. Figure 5 includes this information for both videos. Overall, the principals' evaluation was relatively mixed for both videos with slightly more positive evaluations for Video 1 (42%) and slightly more negative evaluations for Video 2 (46%). As described previously, we selected Video 1 because we thought it was a strong example of science practices, specifically argumentation, while Video 2 did not encompass the science practices, but rather focused on a teacher presenting science facts. The majority of the principals' evaluations did not align with video 1 illustrating more positive science instruction and video 2 illustrating more negative science instruction.

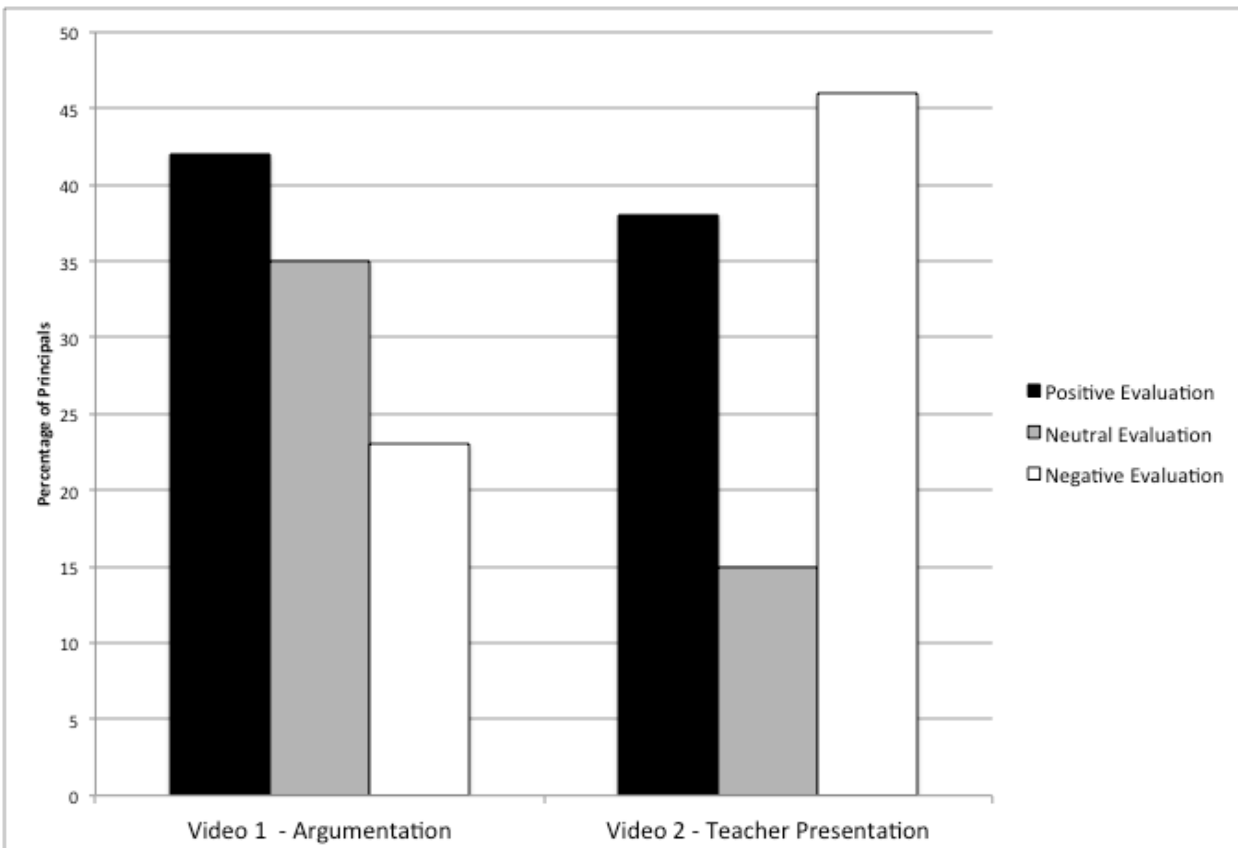

Figure 5 – Principals' overall evaluation of each video example

The misalignment of the principals' critiques to what we viewed as strong science instruction connects back to Theme 3 in which their comments were more likely to be focused on student engagement and pedagogy. The decisions the principals made about the video were often not based on science specific feedback, but rather on other elements of the instruction resulting in a different evaluation. For example, Principal 7 provided a negative evaluation of the students engaging in an argumentation discussion in Video 1 explaining her focus on engagement and pedagogy

> *My thing with teaching and engaging students is how come all the students aren't engaged and what would be other ways to make sure they're all engaged? I like more of students turn and talk or have partnerships and talk about whatever the question is that's posed so everybody gets a chance to talk and share their ideas. Then the teacher picks a few partnerships to share out…I go right into the teaching strategies and not necessarily the content*

As this principal states, her focus is "not necessarily the content", which impacted her negative evaluation. This is similar to Principal 20 who gave a positive evaluation of Video 2 that focused on a teacher presentation. She explained that, "I feel like this is a teacher who knows her kids. They're attentive, engaged. Looks like everybody, that I could see, is really following her and understanding what she's presented."

The principals that did focus on the science practices were more likely to include feedback that aligned with the intended focus of the video. For example, Principal 19 provided a positive evaluation of Video 1 focusing on scientific argumentation stating that, "the teacher is allowing the kids to sort of debate and engage in conversation and defend their statements and sort of counter claims that one or the other might have been making." The comments are focused on the science practice that is the target of the lesson. For Video 2, principals that discussed the science practices were more likely to critique the video because of the lack of science practices. For example, Principal 16 explained

> *She was just telling them a lot of things. She was telling them. This isn't science. This is imparting information and they have to believe her or not. They're not constructing anything here…She could have given them lots of different things, that that are flat, seashells, cups, all kinds of things that might capture sound and that they can hear better, just even piping, and ask them to experiment. What makes the sound more exaggerated? What makes it louder?*

Her negative evaluation was based on the observation that the teacher focused on presentation and the lack of investigation opportunities for the students.

The principals' comments suggested that they were more comfortable focusing on other aspects or even other disciplines, such as literacy and math, which impacted the quality of their evaluation. For example, Principal 12 explained

> *Well, I think – I'm wondering. The content is so specific with science. I mean you're teaching very specific units of study. I think the difference would be the knowledge of the teacher on that subject. When you're an elementary school teacher, I think the focus is in literacy and math. With reading it's always comprehension, fluency, phonics, that doesn't change. With science, the units of study do change.*

This comment is interesting in that the principal recognized elements of literacy (e.g. comprehension, fluency, etc.) that actually cut across different reading or writing activities. The principal did not talk about a unit specific literacy goal, such as for students to remember what happens to the tree and the boy in *The Giving* Tree by Shel Silverstein. This is in contrast to science, where she did not appear to see common elements of science that cut across different units. The focus on science practices provides a potential avenue to offer teachers science specific feedback, without a principal needing expertise in every specific science unit or content area. Principals may not realize that this option is available to them and our findings suggest an important area of support for these instructional leaders.

Discussion

The complexity of the science education system derives in part from the multiple levels of control – classroom, school, district, state and national – that impact decision making and classroom instruction (NRC, 2012). School principals' decisions and instructional leadership ultimately impact students' learning of science (Wenner & Settlage, 2015). Our research suggests that k-8 principals may have limited understandings of what counts as "good" science instruction and need to develop the capacity to effectively supervise science, particularly given recent efforts to reform science instruction.

Investigating Practices and Hands-on Science

One of the reasons for the shift in science education from inquiry to science practices is because teachers often conflated inquiry with investigations and hands-on activities (Osborne, 2014). The principals' responses suggest that they hold similar views of "good" science instruction focusing on investigations without an understanding of the sensemaking or critiquing science practices. Although this indicates a limitation in their current understanding, we also suggest that this inclusion of Investigating Practices (77%) and Hands-on Science (96%) could be used as a lever to support more effective science instruction in k-8 classrooms. Recent reform efforts in ELA have included a shift to disciplinary literacy and the inclusion of non-fiction texts (Hakuta & Santos, 2013). Although we see these literacy connections as important for supporting science, a focus solely on text does not enable students to engage in all eight science practices. Students need to actively engage in investigating, collecting data and making sense of that data for actual phenomena in their classrooms. Using "hands-on" and "investigating" as an important starting point with principals, may help encourage them to value this type of instruction. This initial focus could be used to support the idea that students should be actively engaged in science practices and not just reading about science.

In addition, instructional leaders often make sense of recent reform efforts based on their prior experiences (Spillane, 2004). Consequently, this focus on investigating and hands-on is important to consider as we support principals in understanding recent reform efforts in science. Other elements, such as critique, may differ more from their previous understandings, which could make them challenging for adoption. For example, argumentation prioritizes the consideration and evaluation of multiple competing explanations where students critique different claims using evidence (Osborne, 2010). The type of instruction that supports argumentation is quite different than other pedagogical models, such as the Sheltered Instruction Observation Protocol (SIOP) model that encourages teachers to introduce and define all key concepts and terminology at the beginning of lessons (González-Howard & McNeill, 2016). Instead, the science practices require students to actively engage in sensemaking about phenomena as they construct scientific knowledge (Berland et al, in press). Principals may be more familiar with instructional models that are quite different compared to the science practices.

Noticing Science Specific Elements of Instruction

When actually observing and discussing videos of instruction, science specific characteristics, such as the Investigating Practices or Critiquing Practices, were not prevalent in the principals' comments. Instead, they focused on general pedagogy and student engagement, even more so than when they described "good science instruction." This may relate to the lack of expertise in science; only three of the twenty-six principals held a teaching license in science and many of the principals discussed their lack of knowledge or comfort with science. Principals' understandings of the discipline significantly impact their instructional leadership and supervision (Nelson & Sassi, 2005; Spllane, 2005). Furthermore, the observation protocols typically used by principals focus on general pedagogical features and student engagement (e.g. Danielson, 2002). Consequently, it is not surprising that it was challenging for the principals to effectively evaluate science instruction.

Taken together, these findings suggest that principals need substantial support to serve as effective instructional leaders of science. Not only do they need to develop their understanding of effective science instruction as conceptualized by NGSS, but they also need support building the capacity to 'notice' the science practices. Developing specific observational protocols for science, such as focusing on the science practices, offers one avenue for supporting principals in their observation and evaluation of science instruction. Highlighting key elements that cut across units and topics may help them "notice" or attend to important activities within science classrooms (Sherin et al., 2011). Supporting principals around the science practices could enable greater systematic reform than an approach that focuses solely on science teachers and their students.

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