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Using a video club design to promote teacher attention to students' ideas in science

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HIGHLIGHTS

- Presents design-based research building on prior video club work.
- Offers a new design for a science teaching video club.
- Describes two unique design features tied to teacher noticing outcomes.
- Teachers' use of wearable video technology is significant to this design.
- Results show video club design supports sustained focus on students' thinking.

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ABSTRACT

Science education stakeholders worldwide are engaged in efforts to support teachers' noticing and making sense of students' thinking in science. Here we introduce the design of a science teaching video club and present a study of its implementation. The current design extends prior research on video clubs as a form of professional development for supporting mathematics teachers. Results indicate that the current design supported science teachers in noticing and discussing students' thinking in sustained and meaningful ways.

1. Introduction

Einstein famously said that “the whole of science is nothing more than a refinement of everyday thinking” (1936). Under this premise, teaching science involves attending to the explanations students develop as they interact with the physical world and using those ideas as the basis for learning in the classroom (Barnhart & van Es, 2015; Roth et al., 2011; Ruiz-Primo & Furtak, 2007; Talanquer, Tomanek, & Novodvorsky, 2013). Indeed research on effective science teaching—including responsive teaching (e.g. Coffey, Hammer, Levin, & Grant, 2011), ambitious teaching (e.g. Windschitl, Thompson, Braaten, & Stroupe, 2012), and reform-based teaching (e.g. Schneider, Krajcik, & Blumenfeld, 2005)—finds that attention to students' ideas supports meaningful science learning.

Despite this consensus, attending to students' thinking while teaching science can be quite difficult (Barnhart & van Es, 2015; Windschitl, Thompson, & Braaten, 2011). Doing so requires many teachers to approach science instruction differently than in the past, shifting from attending to students' correct and incorrect answers or usage of science vocabulary to attending to the “initial ideas students bring to school and how they [students] best may develop an understanding” (NRC, 2012, p. 256) of phenomena in the world (Crawford, 2007; Davis & Smithey, 2009; Schweingruber, Duschl, & Shouse, 2007).

In light of this goal, the science education community is engaged in a variety of efforts to support teachers in learning to notice and make sense of students' science ideas so that these ideas become the basis of learning in the science classroom. Here we present one

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such model of professional development (herein referred to as PD). Specifically, we report on the design, enactment, and study of a science teaching video club for elementary teachers focused on noticing students' ideas and thinking. First, we present the theoretical basis and prior work informing this design. Next, we describe our design of a science teaching video club and present a detailed account of the initial implementation with a group of elementary teachers. Finally, we offer evidence that this video club model supports teachers' noticing and making sense of students' ideas and thinking in science. The work presented here follows a design-based research methodology (DBRC, 2003) with prior video club design research, particularly in mathematics education, essentially serving as previous iterations of this work and specifying the focus of investigation for this cycle of inquiry (Cobb, diSessa, Lehrer, & Schauble, 2003; Wang & Hannafin, 2005).

2. Literature review and theoretical foundation

2.1. Professional development as a context for teacher learning: a framing perspective

This study is grounded in a cognitive perspective of teacher learning—specifically the perspective that teachers' *epistemological framing* of science teaching and learning drives much of what happens in practice (e.g. Hammer, Elby, Scherr, & Redish, 2005; Hutchison & Hammer, 2010; Russ & Luna, 2013). Framing in general is a dynamic cognitive construct first offered by sociolinguists and anthropologists as a way of explaining how individuals are able to make sense of and appropriately engage in the myriad of interactions encountered every day (see MacLachlan & Reid, 1994 for review). The premise is that we are able to make sense of an interaction and behave appropriately based on our prior experiences of similar interactions even when contexts overlap.

A teacher's epistemological framing in particular is a teacher's "sense of what is taking place with respect to knowledge" (Scherr & Hammer, 2009). In a science classroom, a teacher's epistemological framing concerns how she thinks about knowledge as it relates to science teaching and learning. A teacher can frame and reframe her idea of science teaching from moment to moment—sometimes it may mean emphasizing definitions of science vocabulary, while other times it may mean asking questions about scientific phenomena. Furthermore, Levin, Hammer, and Coffey (2009) argue that teachers' different learning contexts (e.g. their schooling history, teacher education program, current teaching placement, etc.) influence how they frame their science teaching practice and this influences their instructional decisions. Thus a teacher's epistemological framing is both dynamic, responding to what is happening in the moment, and empirical, drawing on past experiences of practice.

Three main findings result from the body of work on teachers' epistemological framing are important to note as they inform this design research. First, teachers frame the knowledge at play in classroom activity in different ways at different times. Second, these moment-to-moment understandings of what kind of knowledge is appropriate to use and what kind of epistemic practices (Collins & Ferguson, 1993) are valued influence how students and teachers engage in the classroom activity (Hammer et al., 2005; Redish, 2004; Russ & Luna, 2013). And third, there exists a reciprocal relationship between how a teacher frames classroom activity and what she notices during that activity (Russ & Luna, 2013). MacLachlan and Reid (1994) refer to this relationship when they conclude that framing "creat[es] a particular kind of attention" (p. 55). It is this relationship we consider foremost when designing science teaching PD because we want to promote among teachers a particular kind of attention to students' science ideas and thinking. In other words, we want to design PD that engages teachers in noticing and making sense of ideas so that these activities become part of their science teaching experiences, and consequently inform how they frame their practice. Much of recent research on teacher noticing seeks to characterize the nature of this expertise, looking closely at the ways that teachers notice in the context of instruction. For example, Sherin, Jacobs, and Philipp (2011) describe noticing as the process through which teachers simultaneously identify significant features of instruction and work to make sense of what is noticed. In focusing here on epistemological framing, we emphasize the reasons why a teacher will exhibit a particular kind of noticing.

2.2. A need for science teacher PD creating this particular kind of attention

PD plays an important role in education reform generally (Darling-Hammond & McLaughlin, 1995; Garet, Porter, Desimone, Birman, & Yoon, 2001) and in science education reform specifically (CSMTP, 2001; Fishman, Marx, Best, & Tal, 2003). In general, researchers characterized effective PD as tied to teachers' practice, intensive and sustained, and focused on subject specific content (Garet et al., 2001; Guskey, 2003; Wayne, Yoon, Zhu, Cronen, & Garet, 2008; Wilson & Berne, 1999). More specifically, in science education, researchers characterized effective PD as being "rooted in the science that teachers teach and includes opportunities to learn about science, about current research on how children learn science, and about how to teach science" (NRC, 2007, p. 285). While there is evidence of these principles in prior PD efforts (for reviews see Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009, 2010), the science education community has called for more science-specific PD opportunities for elementary teachers in particular (Appleton, 2013; NRC, 2007). Science education researchers have responded to this need and have developed PD contexts and tools involving video of science teaching and learning (e.g. Boehm, Brysch, Mohan, & Backler, 2012; Hiebert & Stigler, 2000; Roth et al., 2011; Wilson, 2013; Zhang, Lundeberg, Koehler, & Eberhardt, 2011). For example, Rosebery, Puttick, and Warren describe a particularly promising approach to providing such opportunities to elementary teachers. They offer an inquiry-based model of PD that engages teachers in their own scientific sense-making as well as in explorations of their students' scientific sense-making by watching and discussing video of their science teaching practice (Rosebery & Puttick, 1998; Rosebery & Warren, 1998; Warren & Rosebery, 1996). This inquiry-based model of PD is similar to another successful model of PD that Sherin and colleagues present (Sherin & Han, 2004; van Es & Sherin, 2008)—the video club model of mathematics teacher PD.

Largely familiar in mathematics teacher learning contexts, a video club is a type of PD experience in which a group of teachers watch and discuss classroom video excerpts of their instruction with a particular focus or framework in mind (Frederiksen, Sipusic, Sherin, & Wolfe, 1998). For example, in order to support teacher learning around a particular classroom issue, teacher discussions in a video club context may be intentionally focused on discourse, student work, student thinking, or management (Tochon, 1999). This model has proven to be effective in supporting teachers' attention to students' mathematical thinking in particular (van Es & Sherin, 2008; Sherin & van Es, 2009).

Like other effective models of teacher PD, both the inquiry-based and the video club models involve the design of PD that is embedded in teachers' practice, focused on the content teachers teach, and sustained over time. In addition, both models use video of practice to engage teachers in conversations around problems of practice. In the last two decades, video has become increasingly popular as a tool for teacher PD. Several affordances of video likely underlie this popularity (Sherin, 2004). First, video has been shown to be a valuable teacher learning tool because it captures the complexity of a classroom and meaningfully reduces that complexity by providing a record of interactions (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Zhang et al., 2011). In addition, because video provides a permanent record of what took place, it invites opportunities for teachers to focus on different aspects of classroom interactions (Sherin, 2004). Similarly and specific to science teacher learning, prior work demonstrates that watching and discussing video of practice supports teachers' learning to notice and make sense of students' thinking (Abell, Bryan, & Anderson, 1998; Levin et al., 2009; van Zee, Hammer, Bell, Roy, & Peter, 2005). As such, we felt it was reasonable to think that a video club focused on students' science ideas could be a particularly good context for supporting in-service teachers' learning to notice and make sense of students' thinking in the science classroom. In this current design work, therefore, we draw on these PD models and prior research and offer a video club design that we expect to be particularly effective in engaging teachers in noticing and making sense of their students' science ideas.

In this work, we utilized a design-based research (DBR) methodology (DBRC, 2003) involving two stages: (1) designing a new video club model for science teachers, and (2) investigating the initial implementation of this new video club model with four elementary school teachers. In the sections that follow, we describe each of these stages of DBR activity.

3. Science teaching video club design

Our design goal was to refine and improve the video club model of PD for science teachers in particular. Our first step in this design work was to examine the outcomes of past mathematics video clubs (Sherin, 2000, 2007; Sherin & Han, 2004; Sherin & van Es, 2009; van Es & Sherin, 2006, 2008, 2010; Sherin, Linsenmeier, & van Es, 2009) to identify features contributing to this PD model's success and also the teacher learning needs that the model did not address. Most mathematics video club design iterations from Sherin and colleagues involve teachers discussing video of their practice that researchers have selected. Typically these video clubs met semi-weekly throughout a school year and focused on teachers discussing and analyzing students' mathematical thinking apparent in the researcher-selected videos. As van Es and Sherin (2010) point out, this “video club design is based on key principles of effective professional development (Penuel et al., 2007). It is closely tied to teachers’ classroom instruction, is long-term and sustained around a specific focus, and encourages teacher inquiry into the particulars of their practice.” (p. 159). The main finding of this work is that this model is effective in supporting teachers in learning to notice and make sense of students' mathematical thinking (van Es & Sherin, 2008). Since we wanted to design for a similar outcome but with science teachers instead, our design shares three key features of these past mathematics video clubs: (1) the central activity: teachers view and discuss video of their practice, (2) the focus: teachers discuss and analyze students' thinking, and (3) the sustained duration: teachers meet semi-weekly during a school year.

In our examination of the outcomes of this prior video club work we also identified two needs that we wished to address, therefore, our design differs in important ways as well. First, we saw that prior work reported that teachers' video club discussions initially focused on pedagogical issues and only over time became focused on mathematical ideas raised by students (Sherin & Han, 2004; van Es & Sherin, 2008). This is not surprising given that prior research has shown that when teachers discuss video of classroom activity, they tend to focus on and evaluate what the teacher is saying and doing (Hammer, 2000; Richardson & Kyle, 1999; Sherin & Han, 2004). Nevertheless, we wondered if it was possible to design a video club in which teachers from the start discuss students' science ideas by focusing on what students are saying and doing instead.

Second, not only did we want to establish and sustain this focus on students' science ideas, we wanted teachers to work to make sense of these ideas in significant ways. Prior work describes teachers' sense-making of students' thinking as involving different activities: (1) describing (i.e. providing an account of such), (2) evaluating for adherence to the canon (i.e. determining correctness), and (3) interpreting what students could have meant in their expressions (i.e. meaning-making) (e.g. Coffey et al., 2011; Crespo, 2000; Russ, Coffey, Hammer, & Hutchison, 2009; Talanquer, Bolger, & Tomanek, 2015). This prior work also demonstrates that these activities serve different purposes in teachers' sense-making pursuit and teachers engage at different levels of depth. Prior research has also shown that teachers must first notice students' ideas in order to be able to make sense of them (Atkin & Coffey, 2003; Sherin et al., 2011; Hutchison, 2008; Jacobs, Lamb, & Philipp, 2010). In fact, past video club research demonstrates this. For example, van Es and Sherin (2006, 2008, 2010) report that in early video club meetings much time was spent on supporting teachers in noticing significant student thinking moments in the videos they viewed. Further, as teachers gained skill in noticing these moments, their sense-making activity commenced in later video club meetings, typically starting as simply restating students' ideas and only over time progressed towards inquiry-based interpretations of these ideas. We suspect then that teachers in these prior video clubs were first learning to notice student ideas, and following this, were then able to engage in sense-making activity around these ideas. We wondered whether we could design a video club in which the interpretive sense-making work occurs from the very start.

To address these needs, we modified the kind of video footage shown in the video club and the way such footage was collected. First, we decided to task teachers with collecting and trimming video footage around specific students' science ideas with the idea that the work of noticing their students' ideas could take place prior to video club meetings so that meeting time could be used for sense-making activity around those ideas. Giving this task to teachers was a striking shift from prior video club designs in which a researcher would videotape a teacher's lesson, review the footage, and select segments displaying students' thinking to be discussed in the meeting. Our challenge, however, was to find a way for teachers to do this without overburdening them. Our solution involved utilizing wearable video technology, specifically the POV 1.5 (V.I.O., 2009), that enables teachers to capture moments of their students' thinking in the midst of teaching science, thus trimming (in real time) the classroom footage to clips containing students' science ideas.

The POV 1.5 (see Fig. 1) consists of a small video camera (which can be attached to the bill of a hat worn by the user), a hand-held remote, and a recording module. This system features technology which allows users to capture and store previous minutes of video, the duration of which is pre-determined by the user. Essentially, the camera continuously records loops of video footage, and when the user presses the “save” button on the remote, both the current and either the prior or subsequent loop of action is stored. In this work, we chose to make these loops 1-min in duration so that the resulting video clips would involve 2-min of footage surrounding the moment the teacher captured. Though this technology is unusual in a classroom context, we have found that teachers have successfully used it to capture classroom moments and students have adjusted to their teacher wearing this camera much as they do

Fig. 1. Teachers used the POV 1.5 to capture students' science ideas.

when any camera is used in a classroom (Sherin & Sherin, 2010).

We saw that by having teachers utilize this wearable technology to capture their students' ideas while teaching science, we could essentially eliminate the time and effort required to collect and trim video footage yet maintain the goal of having teachers notice their students' ideas prior to the video club meetings. Therefore, in this video club design, teachers are asked to wear the camera during science instruction to capture moments of students' thinking that could be viewed and discussed in a video club meeting.

Further, we note that it is not just the task itself but also the product of this task—video footage of specific student ideas from a teacher-point-of-view camera—that becomes an important design feature of our video club. As discussed previously, the use of video as an artifact of practice to support teachers' learning in PD is not new (Borko et al., 2008; Brophy, 2004; Sherin, 2004), nor is it new to a video club model of PD (Sherin & Han, 2004; van Es & Sherin, 2008, 2010). What is unique to our design, however, is the perspective of the video footage we use and the intended recorded activity. In prior video clubs, video footage typically provided an observer's perspective of what occurred during the lesson. The teachers and students are visible in the video as is a wide range of the classroom activity. Our video club design, in contrast, essentially removes the teacher from the video footage by using teacher-point-of-view video clips recorded from the bill of a hat worn by the teacher.[1] The result is close-up video footage that is focused on students. Such footage provides visual and audio details of what students say and do. While the teacher is still audible in the footage, there are no visual cues of the teacher. The idea is that by removing the teacher (at least visually) from these clips, the discussion of these clips might more likely focus on students.

In sum, we believe that these two new design features involving the kind of video footage shown in the video club and the way such footage is collected can support establishing and maintaining early, sustained focus on students' ideas in video club discussions. And because teachers are to record point-of-view video footage of specific instances of students' science ideas prior to these meetings, we believe that they will enter the video club having already experienced the work of noticing students' ideas, at least to some degree, and are therefore ready to engage in sense-making of those ideas from the start. Table 1 summarizes features unique to our video club design.

4. Implementation study: Fuentes Elementary School Science Teaching Video Club

It was our expectation that an implementation of this video club would result in outcomes demonstrating an early sustained focus on students' science ideas where teachers work towards making sense of those ideas. We therefore examined an implementation of this video club design for evidence of such outcomes. Specifically, we sought to answer the following research questions:

1. What topics do teachers focus on in the video club discussions? When do they focus on students' science ideas?
2. How do teachers talk about students' science ideas in the video club discussions?
3. When teachers try to make sense of students' science ideas, what do they focus on?

4.1. *Design-based research methodology*[2]

4.1.1. *School context and teachers*

Four teachers from Fuentes Elementary School volunteered to participate in the video club facilitated by a researcher (the first author[3]). The school serves primarily Hispanic, low SES, and limited English proficient students and was on Academic Early Warning Year 2 under the No Child Left Behind policy (Act, 2002). School leaders emphasized raising reading and math proficiency among students and giving less attention to science instruction. Nevertheless, school leaders supported this PD opportunity and invited the facilitator (first author) to present the video club idea to Fuentes' 3rd-5th grade teachers at an informational meeting. Nine teachers attended this meeting, and five expressed interest in the video club. Of these five teachers, four committed to participating in the video club from January to April and also agreed to teach science at least twice a week, which was, according to them, more frequent than was the norm at Fuentes. The participating teachers taught either 3rd or 5th grade, and had a range of years of teaching experience; two of the classrooms were bilingual (Table 2).

4.1.2. *Teacher-collected video clips*

Prior to the start of the video club, the facilitator met with teachers to introduce the wearable camera and allow them to practice using it until each was comfortable with the wearable technology and his/her ability to capture students' science ideas while teaching science. Then teachers used the POV 1.5 while teaching science at least once between each video club meeting to collect video clips of their students' science ideas. On average, teachers collected 20 video clips each time they wore the camera. As such, there were more teacher-collected clips than were possible to discuss in the video club meetings, and therefore, before each meeting, the facilitator reviewed all the teacher-collected video clips and chose a subset to view in the video club. This clip selection was based on two dimensions identified in prior research as contributing to a productive clip for teacher video club discussion (Sherin, Linsenmeier, & van Es, 2009): (a) Windows: Is there evidence of students' thinking in the clip? and (b) Depth: Are students exploring substantive science ideas? For example, prior to one video club meeting, Rachel captured 16 clips while she taught a lesson on using a thermometer to measure temperature. The facilitator reviewed these clips, and selected one for the video club in which students were engaged in a discussion about how and why a thermometer works. In particular, the selected clip illustrated (a)

[1] It is important to note that the decision to use the POV 1.5 technology in the design of this video club was not an afterthought, but rather an intentional design choice made based on its capabilities. This technology is an integral part of this video club model.

[2] This design implementation research study was undertaken with approval of the Institutional Review Board at the second author's institution.

[3] The first author served as the video club facilitator throughout the duration of this implementation.

Table 1
Design features unique to the science teaching video club.

Design feature	Addresses this need:	How?
Teachers are given the task of capturing students' science ideas while they teach science.	Establish an earlier sustained focus on students' science ideas and thinking in the video club discussions.	By capturing their students' science ideas, teachers are prepared to talk about these ideas during video club discussions of these moments.
Point-of-view teacher collected clips are viewed and discussed in video club meetings.	Provide teachers an entry point into video club discussions of the meaning of students' science ideas. Deter teacher-centered talk in video club discussions.	A point-of-view teacher collected video clip is captured because something about what the student said or did stands out to the teacher in the midst of teaching. This detail can serve as an entry point into the discussion of the idea. By removing the teacher (at least visually) from the clips that are viewed, the discussion of these clips will tend to focus on students rather than on the teacher and hence be less evaluative of the teacher.

Table 2
Teacher participants.

Teacher participant	Years teaching experience	Classroom	# video club meetings attended
Carol Jones	23	5th grade	8
Diego Santiago	21	3rd grade bilingual	6
Rachel Abilla	3	3rd grade bilingual	8
Sue Nichols	23	5th grade	6

Table 3
Sample video clip transcript.

Video club meeting #3	
Clip #1: Ariel's question	
Ariel:	But I have a question
Mrs. Abilla:	Okay, what's your question?
Ariel:	Um, if this, um, I know that it is only a liquid, but when you put it in something cold or hot why does it um, it, how could it go up or down?
Mrs. Abilla:	Right? So your question is why? Why the alcohol is doing this? Going up and going down? Oh, good question. Who knows the answer why? Yes Ricky?
Ricky:	You, you uh, because… [turns the thermometer over in his hand and looks at the back side]
Mrs. Abilla:	Shhh. Listen. Listen to his ideas, okay?
Leo:	Ricky, he says, "oh maybe they, um, or maybe they put like um batteries or energy, so it could go up or down".
Mrs. Abilla:	Ahhh, so, Leo, you are saying that, wait, Ricky, you are saying that you think that maybe you have batteries here? [points to back of the thermometer]
Leo:	I don't think so.
Mrs. Abilla:	You don't think that?
Leo:	Maybe, maybe it's special alcohol.
Mrs. Abilla:	A special alcohol?
Leo:	Or maybe the paint, um, like doesn't stay, like if it, if you turn it upside down, it works all the way over here.
Leo:	Or, or maybe when it's cold, the alcohol is like cold or something. It tries to get up, and…
Students:	No. No.
Mrs. Abilla:	Alright, wait, wait listen to him.
Leo:	… or when it's hot it goes all the way up because um the hot water can go away from the alcohol.
Mrs. Abilla:	The alcohol what?
Leo:	That, maybe, um, the, the alcohol, it's trying to escape from the cold water and the hot water.
Mrs. Abilla:	It's trying to escape? Oh interesting! Okay.
Leo:	And that's why it like, it floats all the way to the top [sits up tall and moves hands upwards in a floating gesture]. Until like the hot thing like…
Mrs. Abilla:	Tries to escape?
Leo:	Yeah.
Mrs. Abilla:	And when it's cold?
Leo:	It goes [shrugs whole body downward] all the way down.

windows into student thinking as students discussed several ideas about how a thermometer works, and (b) depth as students were engaged with substantive science ideas as they puzzled about why the red substance in the thermometer would move up and down in response to being placed in cups of water of differing temperature. In Table 3, we provide an edited transcript of this clip (edited for length) as an example of the type of clip selected for video club discussions.

Once the subset of clips was selected for each video club meeting, the facilitator prepared discussion prompts specific to each clip and based on the phenomena being explored in the lesson, the ideas students raised, and any responses (both teacher and student) to these ideas.

Through the duration of the video club, three of the teachers used the POV camera eight times each and collected a total of 538 2-min clips containing students' ideas.[4] Teachers often captured moments one right after the other, so in selecting clips for the video club meetings, the facilitator sometimes combined several consecutive loops in order to portray the full arc of students' sense-making captured by the teacher with subsequent "saves" on the

[4] One teacher, Sue Nichols, experienced difficulty getting full student consent to videotape her science lessons and thus did not use the camera to capture students' ideas in her classroom. Sue therefore participated in the video club discussions only.

remote. Therefore, the clips viewed and discussed in the video club often contained multiple 2-min segments. Across the 8 meetings, 94 captured segments were discussed in 30 video clips ranging from 2 to 6 min.

4.1.3. Video club structure

The video club met eight times for approximately 70 min from January–April across one school year. The structure of each meeting was the same. First there was a short debriefing in which teachers shared experiences using the camera while teaching science. Next, the bulk of the meeting consisted of viewing and discussing teacher-collected video clips. Generally, 2 to 6 video clips were shown at each meeting. The teacher whose clip was being shown provided background on the lesson and explained where in the lesson the particular clip took place. After viewing each clip, the facilitator asked what the teachers noticed or what stood out to them in the video. Discussion ensued until the teachers felt they had sufficiently made sense of the students' ideas in the clip. Finally, at the end of each meeting, teachers discussed upcoming science lessons and identified ways to provide opportunities for students to share their ideas during these lessons.

In order to convey a sense of the kinds of conversations that took place in the meetings, we provide an excerpt of the teachers' discussion of the thermometer clip (*Ariel's Question*) presented earlier. After the teachers viewed the clip, the facilitator asked what they noticed about the students' ideas. The teachers immediately pointed out Ariel's question—"I know that it is only liquid, but how could it go up or down?"—and in the conversation that followed considered various students' responses to this question—"maybe they put batteries or energy, so it could go up or down" and "maybe it's special alcohol." Specifically, Rachel commented that a student, Leo, had said the thermometer had "a special battery or energy." The teachers then focus on Leo's use of the word "energy." Carol suggests that Leo uses "energy" because he understands that in order for something to move it needs energy. The following excerpt begins at this point in the conversation where teachers discuss Leo's physical movements while he explains what the liquid in the thermometer is doing and agree that he has some understanding of how liquids behave when heated or cooled.

Carol:	He is moving up and down.
Rachel:	It's like a [grunts and shrugs her body down].
Facilitator:	So he's saying when the alcohol is cold or when [the water is] cold the alcohol is cold or something, so he's scrunching down. And then he says "it tries to get up". So what is he doing there? What is he trying to say by that?
Rachel:	I don't know, was he…hmmm? But I think that he was using his body to explain what was happening. See, because I understood that the idea was, when it's cold I do this [shrugs down], you know when it's hot, I do that [sits up tall]. So they relate the alcohol by maybe that way.
Facilitator:	So what you're saying is maybe they are saying alcohol behaves in a way that they would behave if they were cold or hot?
Rachel:	Because that's the prior knowledge that they have. They don't know anything about liquids, but they're relating cold and hot…
Carol:	It expands out.
Rachel:	He says escape. "Maybe the alcohol, it's trying to escape from the cold water and the hot water."
Facilitator:	So what do you think he understands here?
Carol:	I think he understands that liquids react to hot and cold temperatures. Oh, and I think he knows that for something to move it needs energy. But I don't think he connects his ideas or understands that heat is the energy that causes the red substance to move. Not yet.
Rachel:	You know, for him, that's a good explanation. I mean with all of the prior knowledge they know, they only know about the alcohol moving up and down, that's all they know. But Leo uses his experiences with hot and cold temperatures to try to explain what he is seeing. And actually the way a thermometer works is when you do put it in that hot water, and the liquid rises up, it's doing that in reaction to the hot water, so his explanation makes sense, right? Even if he's not using the word "expanding". He has the idea that is what the liquid is doing.

While this excerpt does not provide the entirety of the teachers' discussion of *Ariel's Question*, we use it to illustrate the sense-making that was typical when teachers discussed the students' ideas viewed in the video clips at each meeting. Next, we describe how we analyzed these video club conversations in order to answer our research questions.

4.1.4. Data sources

The eight video club meetings were videotaped from a camera placed to the side of the meeting space. Video footage consisted of 567 min transcribed in preparation for analysis. Since we were interested in examining teachers' talk about the video clips viewed in each meeting, we reduced the data to only include video footage of the discussions of the 30 video clips viewed across the eight meetings. This means small talk, logistics, and talk of future lessons were not part of data analysis.

4.1.5. Data analysis

We examined three aspects of the discussion around the 30 video clips (hereafter referred to as episodes of talk): (1) the general topics of conversation, (2) discussion specifically around students' science ideas, and (3) how teachers talked about students' ideas. In a study of mathematics teachers' learning in the context of a video club, van Es and Sherin (2008) analyzed segments of video club conversations along five dimensions: Actor (i.e., who was noticed), Topic (i.e., what was noticed), Stance (i.e. how they analyzed what was noticed), Specificity, and whether comments were Video-based. Our analysis draws on both this prior work and the data itself resulting in a two-level coding scheme.

1st level coding. The first author segmented the transcripts of each episode of talk based on when a new issue was raised. This is similar to the data chunking method others have used in order to identify a meaningful unit for analysis (Jacobs & Morita, 2002; Grant & Kline, 2004). These segments were then coded according to discussion topic focus. Prior research examining video club conversations identified five topic code categories including Student Thinking, Pedagogy, Climate, Management, and Other (van Es & Sherin, 2008). Using these five topic codes as a basis, the topic coding scheme used in this analysis evolved according to the specifics of these episodes. Four codes emerged, three similar to colleague and author's and one additional: Student Characteristics, Classroom Climate, Pedagogy, and Student Science Idea. (Table 4 provides descriptions and examples of all codes.)

2nd level coding. In the next phase of coding, those segments identified as Student Science Idea underwent additional coding. First, each Student Science Idea segment was further divided into sub-segments based on when a new aspect of the students' idea was raised. These sub-segments were then coded along two dimensions. Sub-segments were coded according to the aspect of the students' idea that was being discussed; four codes corresponded to these different aspects: Source, Action, Meaning, and

Table 4
Summary of two-level coding scheme with codes, descriptions, and examples.

Code	Description	Example
1st level coding		
Dimension: discussion topic focus		
Code	Description	Example
Student Characteristics	Refers to talk centered on a specific attribute of a student or group of students, such as their personality or work style.	"I did not expect him to answer the question because he normally does not say anything, he is usually very quiet."
Classroom Climate	Refers to talk centered on the social environment of the classroom.	"They are enjoying the lesson. The room is very busy with lots of activity and talking."
Pedagogy	Refers to talk centered on some aspect of teaching in general or teaching science specifically.	"I noticed that you [the teacher] first demonstrated what you wanted the students to do in their groups."
Student Science Idea	Refers to talk centered on students' thinking and reasoning about the science at hand.	"He says the balloon has electricity, but I think he means the air in the balloon has electricity."
2nd Level Coding		
Dimension: Aspect of Student's Science Idea being Discussed		
Code	Description	Example
Source	Refers to teachers' talk around where a students' idea came from.	"His dad operates a crane, so he learned that idea from him."
Action	Refers to teachers' talk around students' gestures related to the idea expressed.	"She is moving her hands up and down like a scale."
Meaning	Refers to teachers' talk around the sense of what students could have meant in their expressions.	"Maybe he was thinking that it was the difference between a machine and human being."
Content	Refers to teachers' talk of students' use of specific science content such as science vocabulary and facts.	"He used the word capacity."
Dimension: How the Student's Science Idea was Discussed		
Code	Description	Example
Describe	Refers to teachers' talk that gives an account of events in the clip.	"His idea is that the confetti is not going to stick to the balloon."
Evaluate	Refers to teachers' talk that includes an evaluative statement.	"He is not correct in his idea. He thinks there is no electric charge on the comb but that is not right."
Interpret	Refers to teachers' talk centered on making sense of an idea.	"Well, but previously Jake had made a distinct point about the electricity being inside the balloon. And so when Erwin is saying there's no air, it's like, okay, where can the electricity be? You know, there's no air in the comb. So where would it be?"

Content. In addition, sub-segments were coded for *how* the teachers discussed the student's idea. van Es and Sherin (2008) refer to this dimension as the stance teachers took when discussing students' thinking. Again borrowing from van Es and Sherin's coding framework, three hierarchical codes were used here: Describe, Evaluate, and Interpret. Note that we consider these types of talk as reflecting an increasingly sophisticated continuum of description, evaluation, and interpretation. Therefore, sub-segments coded as evaluative may also include descriptive talk, and those coded as interpretative may also include descriptive and/or evaluative talk.

Summary of coded 1st **level segments and 2**nd **level sub-segments.** Across the 30 episodes of talk in the eight video club meetings, a total of 176 discussion segments were identified and coded. Of the 176 segments, 78 were identified as being focused on *Students' Science Ideas*. These 78 segments were then further subdivided into 130 sub-segments. The first author independently coded all data; the second author then coded a subset of the data for reliability. Inter-rater agreement was 86%; differences were discussed and resolved through consensus.

5. Results

Our analysis reveals three main outcomes:

1. Teachers' talk during the video club discussions focused more on Students' Science Ideas than on other discussion topics, and this talk focused more on Meaning than on other aspects of students' science ideas.
2. The focus on Students' Science Ideas occurred early in the video club meetings and was sustained throughout.
3. During video club discussions, teachers most often interpreted students' ideas and when doing so focused primarily on the meaning of students' expressions.

Next, we explore each of these outcomes in more detail.

5.1. Outcome 1

Teachers' talk during the video club discussions focused more on Students' Science Ideas than on other discussion topics, and this talk focused more on Meaning than on other aspects of students' science ideas. Across the 176 total episodes of video club talk, there were more segments coded as Students' Science Ideas (78 or 44%) than segments coded as Classroom Climate (20 or 11%), Pedagogy (42 or 24%), or Students' Characteristics (36 or 21%). In other words, nearly half of the episodes of talk in the video club meetings were related to the students' ideas evident in the video footage and not the other classroom "noise" (e.g. what the teacher is saying, how the room is arranged, etc.) surrounding that moment. For example, we see this focus on Students' Science Ideas in the talk of a video clip from a lesson Diego taught on static electricity's effect on a balloon, a comb, and a small pile of confetti. The video clip shows varied classroom activity throughout: Diego uses props at different points; Diego asks questions and calls on students; some students raise their hands while others call out their ideas; some respond to Diego in Spanish; a student "tattles" on a classmate; another student comes into the classroom with a specialist teacher and leaves again; many students talk at once and the noise level rises; the teacher counts out loud to quiet the students down, etc. There is a great deal going on in the video clip that could be noticed by the teachers, thus one could imagine many things teachers could discuss besides the students' ideas. Yet, as evident in the following transcript of the video club discussion around this particular clip, the teachers ignore the extra noise and examine one student's ideas (Erwin's).

Rachel:	He says “you electric the girl's hair.”
Diego:	This is like the beginning of an idea, why that happened when I put the balloon with the girl's hair. So I think he started like that, thinking of the hair.
Facilitator:	Okay, so what you're saying is Erwin was kind of just starting to think about the idea. He's at the beginning of an idea. So when he says “you electric the girl's hair.” What do you think he means?
Sue:	That's the term he's chosen to describe that attraction…That's interesting that you're modeling static electricity, attraction with that. It's interesting that he focused on that term “electric”.
Facilitator:	So “you electric the girl's hair,” so he's saying something, this action [gestures rubbing a balloon in hair] to him has something to do with electricity there?
Diego:	Yeah, I think he realized or he understood that the electricity was coming from her hair.
Sue:	And then it went into the balloon

In this excerpt, we see talk focused on Erwin's idea right away as Rachel started the conversation by repeating Erwin's statement, “you electric the girl's hair.” This example is typical of the kind of focus teachers had when discussing video clips in the 77 other instances of episodes of talk focused on Students' Science Ideas, and as seen in the coded data, this focus occurred more often than any other topic foci.

Across these 78 instances of talk focused on Students' Science Ideas, there were 130 sub-segments in which teachers discussed different aspects of students' ideas. Results indicated that 17 (13%) of these sub-segments were focused on where the idea came from (Source), 40 (30%) were focused on students' gestures related to the idea (Action), 58 (45%) were focused on the what the student might have meant (Meaning), and 15 (12%) were focused on references to specific science content in the students' expressions (Content). Nearly half of these sub-segments were coded as Meaning indicating that, during video club discussions of specific student ideas, teachers primarily focused on trying to understand the meaning of students' ideas. This focus on Meaning is evident in the excerpt presented above as the teachers puzzled over Erwin's words. At the end of the excerpt teachers seem in agreement that when Erwin said “you electric the girl's hair” he meant “that the electricity came from the girl's hair” and “then it went into the balloon.” As the conversation continued, the teachers continued to focus on trying to understand the meaning in what Erwin says:

Diego:	[Erwin] was very sure that the comb would not pick up the paper. He thinks that it's not going to be the same because the balloon is gonna have more electricity than the comb.
Facilitator:	So his idea is that no, the paper's not going to stick to the comb, and why…
Rachel:	Maybe he's thinking it's because of the air that is inside of the balloon. He's thinking that “I don't see where the air is in the comb.”
Diego:	He's brought another variable to think about.
Sue:	Well, but previously Jake had made a distinct point about the electricity being inside the balloon. And so when Erwin is saying there's no air, it's like, okay, where can the electricity be? You know, there's no air in the comb. So where would it be?

This excerpt is typical of the kind of conversations teachers had in the 57 instances of episodes of talk focused on Meaning, which, as noted above, occurred more often than teacher discussion of any other idea aspect.

5.2. Outcome 2

The focus on Students' Science Ideas occurred early in the series of video club meetings and was sustained throughout. In order to determine whether this focus on Students' Science Ideas occurred across meetings and held over time, we looked at the distribution of topic foci of video club segments for early (meetings #1–3), mid (meetings #4–5), and late (meetings #6–8) meetings and saw that more segments were focused on Students' Science Ideas in each of these groupings. Fig. 2 illustrates the distribution across these groupings. This analysis indicates then that there was an early, sustained, and greater focus on Students' Science Ideas than on other topics in the video club discussions.

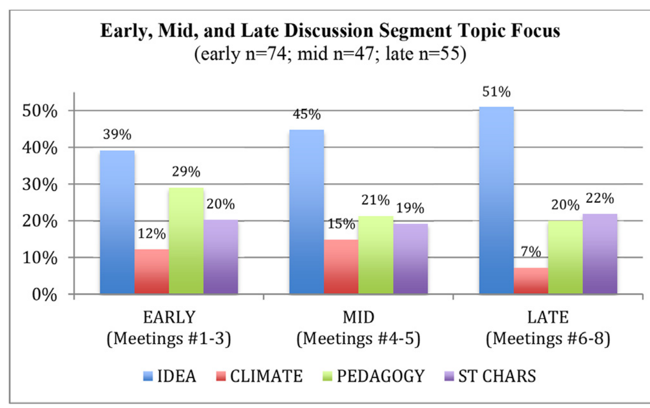

Fig. 2. Focus of teachers' talk during early, mid, and late meetings.

5.3. Outcome 3

During video club discussions, teachers most often interpreted students' ideas and when doing so primarily focused on the meaning of students' expressions. The 130 sub-segments focused on Students' Science Ideas were coded for *how* the teachers talked about the ideas present in the video clips. Results indicated 33 instances of descriptive talk (25%), 13 instances of evaluative talk (10%), and 84 instances of interpretive talk (65%). Table 5 provides an example of each of kind of talk from teachers' discussion of a clip in which students noticed they had different mL

Table 5
Examples of descriptive, evaluative, and interpretive video club talk.

Descriptive Talk	Facilitator: Well why don't we talk about one of their ideas first? Rachel: Okay. Yes, I remember that maybe the water in this vial was up to here and sometimes up to here. That's what it was. Sue: And someone had said on the glass that maybe it got filled up all the way to the top or maybe just about to the top of the top. Facilitator: Okay, so that was another person's idea. So we have two ideas out there. Do those ideas make sense? Diego: Yeah, and I think there was another guy who said the big one was different than the other, in size, than with another table.
Evaluative Talk	Rachel: For me it was interesting, with the first boy, with Joseph, when he uses the word capacity. Sue: That was awesome. Rachel: Because that was the new thing that day, capacity, he was, yes. I think that he's the only one, that he's using that word. Sue: That's awesome. Rachel: It's capacity, teacher. Facilitator: And he used it not just like to use the word, he actually gave you an answer… Sue: And labeled it correctly.
Interpretive Talk	Rachel: David at the beginning said something like "oh teacher you know maybe it's because the vial, the vials", but they [the students] were not able to compare because they did not have the same thing [vials]. But David does not say this, he just said the vials. But Leo thought, "oh yes!". I think that maybe he was just looking around trying to compare the size of the vials. Facilitator: And so his explanation, I think that's why it feels different to me, is that his explanation has, it's… Rachel: More evidence. Yes! Oh, that's evidence! Sue: David says "I think", and then Leo says "I saw", the bigger ones are bigger, the smaller ones are smaller. And so, like a scientist, he backed up why he's saying that.

results after measuring the amount of water in a small vial.

Similarly, across the video club meetings, teachers discussed specific clips by engaging in all three kinds of sense-making talk indicated in this analysis. However, as seen in the number of episodes of talk coded as interpretive, teachers engaged most often in this form of sense-making. We also saw patterns in what aspect of students' ideas teachers talked about and how they talked about these ideas. For example, when teachers' talk focused on Meaning and Source, it was more likely to involve interpretive talk over other kinds of talk; when teachers' talk focused on Action, it was equally likely to involve descriptive or interpretive talk; and when teachers' talk focused on Content, it was more likely to involve descriptive talk. Interestingly, teachers' talk about the different idea aspects included all three kinds of sense-making with the exception of Meaning. Teachers did not focus on evaluating students' ideas when they were trying to understand the meaning behind those ideas (Table 6).

Finally, in order to determine whether this trend towards greater interpretive talk held over time, we divided the data at the same three points—early, middle, and late meetings—and examined the distributions of teachers' sense-making activity at each of these points. Interestingly, the early and middle distributions look very similar. At mid-point there was a slight increase in evaluative talk accompanied by a slight decrease in descriptive talk in the video club discussions. Otherwise throughout the early and middle meetings the level of interpretive talk was consistent at just over 50%. The late point distribution however indicates a rather different picture of sense-making talk. Interpretation increased by 20% while description and evaluation decreased by nearly half of what it was. This result indicates that in this implementation of the science teaching video club teachers often engaged in what we consider the most sophisticated form of sense-making indicated in this analysis (interpretation) across time but more so in the later meetings of the video club in particular. Fig. 3 illustrates this result.

Table 6
Teacher sense-making talk and the focus of each when discussing Students' Science Ideas.

# of episodes (n = 130)	Focused on source	Focused on action	Focused on meaning	Focused on content
Descriptive Talk	5	16	4	8
Evaluative Talk	1	8	0	4
Interpretive Talk	11	16	54	3

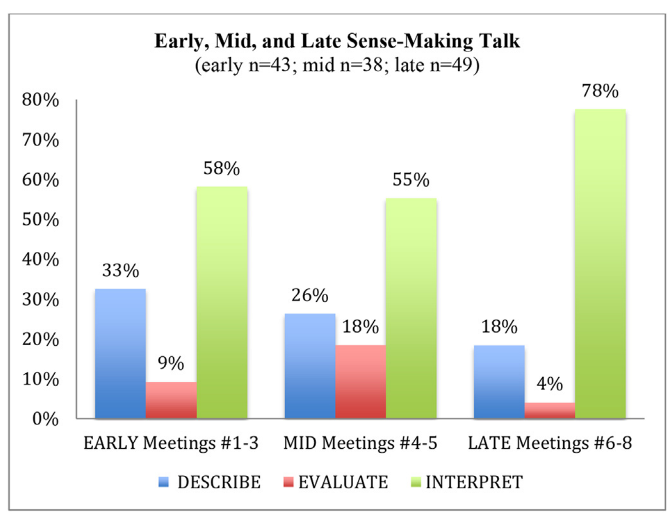

Fig. 3. Type of teachers' sense-making talk during early, mid, and late meetings.

6. Discussion

The expectation of this work was that this design of a science teaching video club incorporating both old and new features would result in a sustained focus in teacher conversations on noticing and making sense of students' science ideas. The analysis of the Fuentes

Elementary School Science Teaching Video Club described here demonstrates that this expectation was met. The combination of using what worked with prior video clubs and two additional features resulted in a video club design that supported teachers in talking about student thinking early, often, and in meaningful ways. Additionally, it created the conditions for teachers to successfully engage in identifying and making sense of students' science ideas. While it is likely other contextual factors contributed to these outcomes, we think it is reasonable to attribute some of these to the two new features of our video club design—giving teachers the task of collecting video of their students' science ideas and the teacher point-of-view video footage.

The design feature of having teachers capture in-the-moment video of students' science ideas was motivated specifically by the need to establish an early sustained focus on students' ideas in video club discussions. The intention was that by engaging teachers in this task, it would prepare them to frame the work of the video club as discussing their students' science ideas rather than other teaching and learning topics. If they did frame the work of the video club in this way, we expected to see the focus of video club discussions on Students' Science Ideas more than other topic foci. This is what we found. Additionally, by using teacher-captured video in the video club discussions, teachers' sense-making of their students' thinking was authentically tied to their practice. The facilitator was able to guide this process by asking questions surrounding specific student thinking moments already noticed in these teachers' practice. In other words, because the teachers already noticed moments of students' thinking, the idea was that their work in the video club would be to make sense of these moments. If this design feature supported such a stance, we expected to see teachers interpreting students' ideas and thinking in the video club meetings over simply describing and/or evaluating those ideas. This is also what we found.

In prior work, van Es and Sherin (2008) found that teachers participating in a video club did come to focus on students' mathematical thinking, but an analysis of these meetings showed that this happened over time:

> In fact, these findings show that it was hard for these teachers to examine video in the ways they were asked. Early on, several of the teachers often focused on actors other than the student, particularly, the teacher or the curriculum developers. In addition, they raised other topics, namely, pedagogy and climate, and they continued to describe or evaluate what they noticed. … In fact, this study reveals that it was not a simple matter for this group of teachers to talk about classroom interactions in the ways they were being prompted by the facilitator. (p.265)

The design presented here, however, eases this task and supports teachers in talking about their students' ideas almost immediately. To be clear, we are not arguing that their conversations are immediately and always substantive, but rather that the video club design with these new features provides the conditions for the successful outcomes described here.

Also, the design feature of using teacher point-of-view clips was motivated by the desire to minimize teacher-centered talk and promote talk of what students are doing and saying in the video clips. We hoped that this would provide teachers a way to enter video club discussions with the intent to discuss students' thinking in science. The idea here is that since point-of-view video clips remove visual cues of the teacher, viewing such footage in the video club context may make it less likely that teachers will talk about what the teacher is saying, doing, and meaning and more likely they will talk about what students are saying, doing, and meaning. Again, this is what we found. Not only did teachers quickly focus on students' science ideas, they did so by specifically exploring students' words and actions in the video as a means to either identify and deconstruct students' ideas or to provide evidence for the meaning behind students' ideas. This is why we think our results indicate that when discussing specific student science ideas teachers primarily focused on action and meaning of students' ideas rather than on source or content. The visual and auditory cues of students' words and actions in the video footage were the elements teachers could attach meaning to, and therefore they did so.

We did expect teachers to also focus more on the science content in students' ideas, however, this was not the case. Even when teachers discussed specific science content in a students' expression (e.g. mentioning specific science terms and facts), they tended to describe and evaluate that content rather than unpack students' understanding of the content. This minimal focus on the science content within students' expressions is important because prior research contends that elementary teachers' lack of science content knowledge presents a barrier to effective science teaching (Appleton, 2003; NRC, 2007). Perhaps our teachers faced the same barrier—they noticed students' expressions of specific science content, but if they themselves did not have deep conceptual understanding of that content it is possible they could not make sense of the students' thinking surrounding that content in a substantive way. In future iterations of our design, we can address this concern by drawing on the prior work of others who have designed PD with the goal of building teacher content knowledge (NRC, 2007).

Our findings about teachers' noticing in the video club are also supported by comments made by the teachers themselves in their exit interviews. While our analysis of this exit data is preliminary, we report an initial finding here. In particular, all four teachers identified two ways in which participation in the video club had supported them in noticing and making sense of their students' ideas. First, they said it broadened what they considered to be an idea in a science lesson. That is, discussing students' ideas with colleagues helped them to become more aware of the range of student thinking taking place in their classrooms. For example, Rachel explained that she found herself thinking about students' ideas in new ways:

> [I see now that their] ideas are not always the same … Sometimes good ideas are in something they did or something they asked. [Before the video club] I didn't think about ideas like that. But good ideas come from lots of moments, and I have to be prepared … When I'm teaching, I need to prepare the ground, the soil or something, for ideas to start growing. Otherwise they can't. It's not just like magic.

Second, the teachers explained that the video club had helped them to focus more on the meaning of their students' ideas rather than on only accuracy and correctness. For example, Carol talked about shifting from listening only for correct answers to listening for meaning:

> At first when we started this, I was only looking for the right answers and the vocabulary from the book, the definitions. I still want that, I want my students to know the science vocabulary. But talking with [my colleagues] in the video club… I learned that my students say and do lots of things that help them learn and now I pay attention to those things so I can understand what they are thinking.

Similarly, Diego shared the importance he now gives to listening for students' ideas and allowing space for students to share their thinking.

> [Now] when I try to understand what [my students] mean, I give more time for different questions and answers and I am not so afraid to let the class continue another way that maybe I never saw or heard before, with those different ideas. Because I can be prepared to hear some kind of answer but sometime somebody's going this way [indicates opposite way] and maybe I am not prepared to make questions for him so I would just move on. But in this [video club] I learned that when I am teaching maybe [the student's idea] is not going to be what I asked—what is a gram, or what is heavy—but it's a nice way to continue. If I listen for what they could mean, it is nice and it helps them learn.

The teachers' perception that the video club supported them in learning to notice students' science ideas corresponds with our findings discussed here. Furthermore, while this study did not include a direct measure of change in teachers' practice, this interview data suggests that teachers not only perceive value in the video club supporting their noticing practices, but that in addition, they see changes in their teaching practices as well.

Finally, we want to note that we are not surprised that teachers took an interpretive stance towards their video club practice—this was the intended outcome of our design decisions. We are surprised, however, and quite curious about the nuance of these teachers' interpretive stance as it demonstrates something we did not consider in our design specifically. Their stance involved understanding where ideas came from, what science content is evident in the ideas, how students' actions demonstrate their thinking, and what meaning is behind the ideas being expressed. Additionally, primarily for these teachers, it was what students were saying *and* doing that provided insight into students' thinking. Yet prior research indicates that when teachers discuss students' thinking in science they often describe what students are doing absent of interpretation of meaning (Gearhart et al., 2006; Sandoval, Deneroff, & Franke, 2002). Our teachers, however, considered students' words, actions, source, and meaning in their interpreting work. In other words, the video club discussions were not absent of interpretation even though they often focused on more than just the meaning of students' expressions. Interpreting students' actions in particular became an important part of these teachers' sense-making process in the video club. Since we did not design intentionally around supporting this nuanced interpretive stance, we are curious as to why we see this difference from prior work. Is it that in this prior work, teachers' talk of what students are doing in science is actually part of the teacher sense-making process that we have not considered? Clearly students' words and actions are laden with meaning as students explore and experience phenomena in the physical world. Furthermore, in recent science education reform efforts, the practices of science are not divorced from the core ideas of science (Davis & Smithey, 2009; NRC, 2012; Schweingruber et al., 2007). In other words, thinking and learning in science involves multiple aspects including using knowledge and actions to reason about scientific phenomena in the world. So it makes sense to us that teachers adopted this nuanced interpretive stance considering all of these aspects as they sought to make sense of students' ideas in science. We see this as another line of research to pursue in this work: In what ways does teachers' attention to what students are doing AND saying in science classrooms support children's learning as they pursue coherent scientific understanding of how the physical world works? And importantly, how do we support teachers in developing this nuanced interpretive stance as we return to the design process and work to improve our science teaching video club model of PD?

We also want to mention two limitations of the current study. First, the small number of teachers participating in the study prevents us from generalizing beyond the current study. Additional research is needed in order to determine the applicability of the design features presented here for promoting teacher attention to students' science ideas on a broad scale. Second, in describing the video club, we focused on several key features of the design. While we believe these features represented significant changes from previous video clubs models, in addition, it seems likely that other features also played a role in promoting teacher attention to students' science ideas. For example, the facilitator's comments during the meetings, the specific clips selected by the facilitator, and the teachers' interactions with their peers during the meetings may have also contributed to the early and sustained focus on students' thinking. In future research we plan to extend the current study to further unpack the ways in which a variety of features of the design mediated teachers' attention in the video club.

7. Conclusion

Our analysis shows that from the first video club meeting to the last teachers did notice and make sense of their students' ideas in science. Furthermore, because these activities were established from the beginning as their “video club practice”, teachers were able to sustain this focus over the course of the eight meetings. As a result of this design research, several important questions remain for us and provide the motivation for future design iterations and research, some of which have already been discussed. Our immediate next step in this work involves examining the role of the facilitator and the facilitator/teacher relationship in this implementation of our science teaching video club. Other researchers have looked at the facilitator/teacher interactions in video clubs and have found that the facilitator's role in initiating and sustaining the work of the video club remains fairly consistent and heavily scaffolded across the duration of the video club meetings (Coles, 2013; Gaudin & Chaliès, 2015). We wonder if we would find the same kind of consistency and primacy in the facilitator role in our science teaching video club across the eight meetings, or would the facilitator and teacher relationship and roles change. To answer this, we need to return to our data and examine how the facilitator prepared for the video club discussions, what facilitator moves during video club discussions supported specific teacher moves, the level of facilitator and teacher participation in these discussions, whether this level changed over time, and the ways in which our video club design features contributed to this facilitator/teacher relationship.

In this manuscript we presented design research involving video-based teacher professional development. Specifically we offered a design of a science teaching video club and investigated whether it was effective in engaging teachers in noticing and making sense of their students' science ideas. The results of this design research indicate that this particular video club design supported teachers in talking about student thinking early, often, and in meaningful ways. This work is both important and timely. For example, as K-12 science education shifts towards a reform-oriented vision, teacher learning opportunities grounded in this vision must be available and “the use of technology-facilitated approaches—such as teachers' video clubs to study their practices collaboratively or the use of geospatial or modeling technology—-while rare today, may become commonplace” (NRC, 2012, p. 260). Clearly science education leaders recognize the potential of science teaching video clubs as a form of PD, and the new video club design presented in this work creates the conditions for a successful implementation in which teachers engage in sustained noticing and making sense of students' ideas in science.

References

Abell, S. K., Bryan, L. A., & Anderson, M. A. (1998). Investigating preservice elementary science teacher reflective thinking using integrated media case-based instruction in elementary science teacher preparation. *Science Education, 82*(4), 491–509.

Act, N. C. L. B. (2002). United States department of education. *Section, 625*, 104–208.

Appleton, K. (2003). How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education, 33*(1), 1–25.

Appleton, K. (Ed.). (2013). *Elementary science teacher education: International perspectives on contemporary issues and practice*. New York: Routledge.

Atkin, J. M., & Coffey, J. (Eds.). (2003). *Everyday assessment in the science classroom*. Arlington, VA: National Science Teachers Association.

Barnhart, T., & van Es, E. (2015). Studying teacher noticing: Examining the relationship among pre-service science teachers' ability to attend, analyze and respond to student thinking. *Teaching and Teacher Education, 45*, 83–93.

Boehm, R. G., Brysch, C. P., Mohan, A., & Backler, A. (2012). A new pathway: Video-based professional development in Geography. *Journal of Geography, 111*(2), 41–53.

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education, 24*(2), 417–436.

Brophy, J. (Ed.). (2004). *Using video in teacher education*. Amsterdam: Elsevier Ltd.

Cobb, P., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13.

Coffey, J. E., Hammer, D., Levin, D. M., & Grant, T. (2011). The missing disciplinary substance of formative assessment. *Journal of Research in Science Teaching, 48*(10), 1109–1136.

Coles, A. (2013). Using video for professional development: The role of the discussion facilitator. *Journal of Mathematics Teacher Education, 16*(3), 165–184.

Collins, A., & Ferguson, W. (1993). Epistemic forms and epistemic games: Structures and strategies to guide inquiry. *Educational Psychologist, 28*(1), 25–42.

Committee on Science and Mathematics Teacher Preparation. (2001). *Educating teachers of science, mathematics, and technology: New practices for the new millennium*. Washington, DC: National Academy Press.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613–642.

Crespo, S. (2000). Seeing more than right and wrong answers: Prospective teachers' interpretations of students' mathematical work. *Journal of Mathematics Teacher Education, 3*(2), 155–181.

Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan, 76*(8), 597–604.

Davis, E. A., & Smithey, J. (2009). Beginning teachers moving toward effective elementary science teaching. *Science Education, 93*(4), 745–770.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

Einstein, A. (1936). Physics and reality. *Journal of the Franklin Institute, 221*(3), 349–382.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*(6), 643–658.

Frederiksen, J., Sipusic, M., Sherin, M., & Wolfe, E. (1998). Video portfolio assessment: Creating a framework for viewing the functions of teaching. *Educational Assessment, 5*(4), 225–297.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915–945.

Gaudin, C., & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Educational Research Review, 16*, 41–67.

Gearhart, M., Nagashima, S., Pfotenhauer, J., Clark, S., Schwab, C., Vendlinski, T., Osmundson, E., Herman, J., & Bernbaum, D. (2006). Developing expertise with classroom assessment in K-12 science: Learning to interpret student work. Interim findings from a 2-year study. *Educational Assessment, 11*(3–4), 237–263.

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan, 84*(10), 748–750.

Hammer, D. (2000). Student resources for learning introductory physics. *American Journal of Physics, 68*, S52–S59.

Hammer, D., Elby, A., Scherr, R., & Redish, E. F. (2005). Resources, framing, and transfer. In J. P. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 121–154). Greenwich, CT: Information Age Publishing.

Hiebert, J., & Stigler, J. W. (2000). A proposal for improving classroom teaching: Lessons from the TIMSS video study. *The Elementary School Journal, 101*(1), 3–20.

Hutchison, P. S. (2008). *Epistemological authenticity in science classrooms* (Unpublished doctoral dissertation). College Park: University of Maryland.

Hutchison, P., & Hammer, D. (2010). Attending to student epistemological framing in a science classroom. *Science Education, 94*(3), 506–524.

Jacobs, V. R., Lamb, L. L., & Philipp, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education, 41*, 169–202.

Jacobs, J. K., & Morita, E. (2002). Japanese and American teachers' evaluations of videotaped mathematics lessons. *Journal for Research in Mathematics Education, 33*(3), 154–175.

Levin, D. M., Hammer, D., & Coffey, J. E. (2009). Novice teachers' attention to student thinking. *Journal of Teacher Education, 60*(2), 142–154.

MacLachlan, G. L., & Reid, I. (1994). *Framing and interpretation*. Melbourne: Melbourne University Press.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8. R.* In D. H. Schweingruber, & A. Shouse (Eds.). Washington, DC: The National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921–958.

Grant, T. J., & Kline, K. (2004). The impact of long-term professional development on teachers' beliefs and practice. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Redish, E. F. (2004). A theoretical framework for physics education research: Modeling student thinking. In E. Redish, & M. Vicentini (Eds.), *Proceedings of the enrico fermi summer school, course CLVI*. Bologna: Italian Physical Society.

Richardson, V., & Kyle, R. S. (1999). Learning from videocases. In M. Lundeberg, B. Levin, & H. Harrington (Eds.), *Who learns what from cases and how? The research base for teaching and learning with cases* (pp. 121–136). Hillsdale, NJ: Erlbaum.

Rosebery, A. S., & Puttick, G. M. (1998). Teacher professional development as situated sense-making: A case study in science education. *Science Education, 82*, 649–677.

Rosebery, A. S., & Warren, B. (1998). *Boats, balloons & classroom video: Science teaching as inquiry*. Portsmouth, NH: Heinemann Educational Books.

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased lesson analysis: Effective science PD for teacher and student learning. *Journal of Research in Science Teaching, 48*(2), 117–148.

Ruiz-Primo, M. A., & Furtak, E. M. (2007). Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry. *Journal of Research in Science Teaching, 44*(1), 57–84.

Russ, R. S., Coffey, J. E., Hammer, D., & Hutchison, P. (2009). Making classroom assessment more accountable to scientific reasoning: A case for attending to mechanistic thinking. *Science Education, 93*(5), 875–891.

Russ, R. S., & Luna, M. J. (2013). Merging research traditions: Inferring teacher epistemological framing from local patterns in teacher noticing. *Journal of Research in Science Teaching, 50*(3), 284–314.

Sandoval, W., Deneroff, V., & Franke, M. (2002). Teaching as learning, as inquiry: Moving beyond activity in the analysis of teaching practice. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Scherr, R. E., & Hammer, D. (2009). Student behavior and epistemological framing: Examples from collaborative active-learning activities in physics. *Cognition and Instruction, 27*(2), 147–174.

Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching, 42*(3), 283–312.

Schweingruber, H. A., Duschl, R. A., & Shouse, A. W. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Sherin, B. L., & Sherin, M. G. (2010). Freezing time: What mathematics and science teachers see while teaching. In *Proceedings of the 9th International Conference of the Learning Sciences* (Vol. 2, pp. 180–181). International Society of the Learning Sciences.

Sherin, M. G. (2000). Viewing teaching on videotape. *Educational Leadership, 57*(8), 36–38.

Sherin, M. G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Vol. 10. Using video in teacher education* (pp. 1–27). Oxford: Elsevier.

Sherin, M. G. (2007). The development of teachers' professional vision in video clubs. In R. Goldman, R. Pea, B. Barron, & S. Derry (Eds.), *Video research in the learning sciences* (pp. 383–395). New York: Routledge.

Sherin, M. G., & Han, S. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education, 20*(2), 163–168.

Sherin, M. G., Jacobs, V. R., & Philipp, R. A. (Eds.). (2011). *Mathematics teacher noticing: Seeing through teachers' eyes*. New York: Routledge.

Sherin, M. G., Linsenmeier, K. A., & van Es, E. A. (2009). Selecting video clips to promote mathematics teachers' discussion of student thinking. *Journal of Teacher Education, 60*(3), 213–230.

Sherin, M. G., & van Es, E. A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education, 60*(1), 20–37.

Talanquer, V., Bolger, M., & Tomanek, D. (2015). Exploring prospective teachers' assessment practices: Noticing and interpreting student understanding in the assessment of written work. *Journal of Research in Science Teaching, 52*(5), 585–609.

Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice? *Journal of Research in Science Teaching, 50*(2), 189–208.

Tochon, F. V. (1999). *Video study groups for education, professional development, and change*. Madison, WI: Atwood Publishing.

van Es, E. A., & Sherin, M. G. (2006). How different video club designs support teachers in "learning to notice". *Journal of computing in teacher education, 22*(4),

125–135.
van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education, 24*(2), 244–276.
van Es, E. A., & Sherin, M. G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education, 13*(2), 155–176.
V.I.O. Inc. (2009). *POV. 1.5*. Retrieved on 21 September, 2009 from: http://www.vio-pov.com.
Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development, 53*(4), 5–23.
Warren, B., & Rosebery, A. S. (1996). "This question is just too, too easy!" Students' perspectives on accountability in science. In L. Schauble, & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 97–125). Mahwah, NJ: Lawrence Erlbaum Associates.
Wayne, A. J., Yoon, K. S., Zhu, P., Cronen, S., & Garet, M. S. (2008). Experimenting with teacher professional development: Motives and methods. *Educational Researcher, 37*(8), 469–479.
Wei, R. C., Darling-Hammond, L., & Adamson, F. (2010). *Professional development in the United States: Trends and challenges*. Dallas, TX: National Staff Development Council.
Wei, R. C., Darling-Hammond, L., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Dallas, TX: National Staff Development Council.
Wilson, S. M. (2013). Professional development for science teachers. *Science, 340*(6130), 310–313.
Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad, & P. D. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 173–209). Washington, DC: American Educational Research Association.
Windschitl, M., Thompson, J., & Braaten, M. (2011). Ambitious pedagogy by novice teachers: Who benefits from tool-supported collaborative inquiry into practice and why. *Teachers College Record, 113*(7), 1311–1360.
Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*(5), 878–903.
van Zee, E. H., Hammer, D., Bell, M., Roy, P., & Peter, J. (2005). Learning and teaching science as inquiry: A case study of elementary school teachers' investigations of light. *Science Education, 89*(6), 1007–1042.
Zhang, M., Lundeberg, M., Koehler, M. J., & Eberhardt, J. (2011). Understanding affordances and challenges of three types of video for teacher professional development. *Teaching and Teacher Education, 27*(2), 454–462.