2-18-2020

Developing a Critical Discourse About Teaching and Learning: The Case of a Secondary Science Video Club

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Abstract

Video is used widely to support teachers' learning and enactment of responsive instruction. Informed by principles of video club design, we designed a video club to support secondary science teachers developing a vision of responsive teaching, attention to student thinking, and a critical discourse to analyze their own and others' efforts to enact responsive practices. In this study, we investigate if and how teachers developed a critical discourse in this context. Analysis reveals that the group developed a more collaborative, interpretive, and evidence-based discourse about teaching and learning. These findings contribute to research on video clubs as a professional development model to support teacher learning, as well as makes visible how teachers shifted to develop a more critical lens for discussing teaching and learning. This study has implications for designing professional learning that will result in sustained, generative development in the context of instructional reform.

Keywords: professional development; science education; teacher collaboration; noticing; video club

Science education reforms advocate for students to engage with and make sense of phenomena to gain deep and enduring understandings of scientific concepts, develop practices for doing science, and construct identities as scientific thinkers and doers (Next Generation Science Standards Lead States, 2013; National Research Council, 2007, 2012; Schwarz, Passmore, & Reiser, 2017). This emphasis on the *practices* of science rather than recall of the *products* of science requires an instructional shift in both the types of tasks students engage in and the type of discourse surrounding these tasks (Thompson et al., 2016; Windschitl, Thompson, & Braaten, 2018). Teaching that focuses on and takes up students' ideas as they engage in rigorous tasks is referred to as responsive teaching (Richards & Robertson, 2016).

Video-based professional development has emerged as a method for supporting teachers to learn to enact responsive practices (Author, 2009a; Borko et al., 2008; Gaudin & Chaliès, 2015; Kang, 2007; Tekkumru-Kisa & Stein, 2017; Roth et al., 2011; Zhang, Lundeberg, Koehler, & Eberhardt, 2011). This study focuses on one model of video-based professional development - a video club - that brings teachers together to view and analyze videos from their own and others' classrooms (Sherin, 2007). Given the demands placed on teachers to achieve the vision set forth for science instruction, and the affordances of video clubs for supporting teacher learning, we drew on the principles of video club design to create a context for secondary science teachers to develop a vision of responsive science instruction and practices for critically analyzing instruction (Author, 2009a, 2009b, 2014; Lord, 1994). We conjectured that if participants in the video club were supported with particular tools and norms as they viewed artifacts of teaching and learning that featured students' science reasoning, they would develop more sophisticated skills for attending to, analyzing, and discussing possible responses to students' ideas during instruction. In this paper, we ask if and how teachers develop a critical discourse of science instruction through focused inquiry and deliberation of science instruction.

Noticing and Critical Discourse as the *What* and *How* of Teacher Learning

We locate this study in the long line of literature that recognizes that teacher learning is situated (Author, 2008; Putnam & Borko, 2000; Horn & Little, 2010; Little, 2002). This literature recognizes that participation in teacher learning communities can provide opportunities for teachers to engage with colleagues and tools to develop knowledge, discourse, and professional practices to transform instruction (Putnam & Borko, 2000). Drawing on Goodwin

(1994), we conceptualize teacher learning as developing a professional vision. That is, teacher learning through participation in professional development involves shifts in both *what* teachers come to notice as salient in their profession, and *how* they talk about their profession. We draw on the constructs of teacher noticing and critical discourse to examine science teacher learning as they collaborate with colleagues in a professional learning context.

The construct of teacher noticing captures two interrelated processes - teachers' attention to and interpretation of noteworthy classroom events and interactions (Author, 2008; Mason, 2009). Individuals notice all the time, but what is noticed varies based on a person's histories, experiences, expectations, and values (Elby & Hammer, 2010). Lacking support for analyzing their practice, teachers typically focus on themselves or aspects of classroom management and climate rather than the substance of students' ideas (Author, 2005; Sherin & Han, 2004; Tripp & Rich, 2012). When teachers do focus on student thinking, they often adopt a descriptive or evaluative stance that results in simplistic assessments of the correctness and accuracy of students' ideas, which leads to normalizing problems of practice in general terms. However, research finds that adopting a stance of inquiry to analyze practice promotes teachers' collaborative sensemaking and interpretation of the complex relationship between student thinking and instruction (Horn & Little, 2010).

Research also finds that professional development can support teachers shifting both what they notice and how they interpret what they observe (Author, 2006; Johnson & Mawyer, 2019; Tekkumru-Kisa & Stein, 2017). In other words, noticing can be directed, focused, and honed (Author, 2006; Dalvi & Hoffman, 2019; Levin, Hammer & Coffey, 2009; Luna, Selmer, & Rye, 2018; Russ & Luna, 2013). In a responsive teaching classroom, what is valued are the ideas and experiences students contribute to a learning situation and how they connect to the discipline (Levin, Hammer, Elby, & Coffey, 2012; Levin & Richards, 2011). Cultivating noticing of students' thinking is integral to responsive teaching because "what you do not notice, you cannot act upon" (Mason, 2002, pp. 7).

How teachers make sense of what they attend to, and thereby how noticing is transformed into knowledge that informs teaching, is by making their noticing public. It is through interaction that shared meaning is negotiated and reified (Horn & Little, 2010; Wenger, 1998). Research has long told us that the organization of professional interactions matters for teacher learning (Ermeling, 2010; Little et al., 2003; Vescio, Ross, & Adams, 2008). Given the idiosyncratic and isolated nature of professional learning, the character of teachers' discussions largely serve to offer support and praise (Ball & Cohen, 1999), in contrast to research that finds that deliberate, focused examinations of teaching and learning, grounded in classroom interactions, can lead to improvement (Cohen & Ball, 1999; Horn & Little, 2010).

Lord (1994) introduced the concept of "critical colleagueship" (p. 192) to articulate a type of professional discourse to transform teaching. Recognizing the demands placed on teachers to enact curriculum reform initiatives, he advocated for professional development centered on the cultivation of a critical stance toward the work of teaching, in which teachers participate in sustained productive disequilibrium through dialogue with colleagues and ongoing critique. This involved new forms of participation and discourse, including embracing intellectual values such as openness to new ideas and increasing comfort with ambiguity and uncertainty; grounding conversations in evidence and reasoning; participating in organized and deliberate investigations of teaching; increasing capacity for empathic understanding; honing skills of listening, discussing, and resolving competing interests; and foregrounding collective generativity as a goal for professional learning (p. 193). Lord argued that professional development, that has as its aim the transformation of teaching, can be assessed through the growth of these attributes.

Explicit parallels can be drawn between the discourse Lord describes and aspects of what Mason (2002) notes as *the discipline of noticing*. Public noticing involves "interweaving strands of your own experience with those of others, constantly seeking resonance, negotiating similarities and differences, locating issues, understandings and possible behavior to employ in the future . . . thus it is vital to find some effective and consistent way of exposing one's own noticing to others," (Mason, 2002, pp. 90). It is through critical discourse that teachers make meaning of the shared object of their noticing. We turn now to consider the role of video in professional development contexts to support both noticing and the development of critical discourse.

Video Clubs as a Professional Learning Context to Support Noticing and Critical Discourse

Video clubs show promise for supporting teachers to develop both their noticing skills for responsive teaching, as well as a discourse focused on inquiry and in-depth analysis of teaching. With the widespread availability of video capture technology and the ease of uploading and sharing video, a video club can be organized with little support from external resources (Author, 2015). In addition, because videos typically come from participating teachers' classrooms and school contexts, they are familiar to teachers and can be seen as sites for change and improvement (Seidel et al., 2011). Video clubs are also flexible to the needs of teachers. They are an example of what Borko and colleagues (2011) refer to as *highly adaptive* professional development because the design emerges in the enactment and can be responsive to local needs. Therefore, they can be readily adopted by instructional leaders and teachers for use in their own contexts for their own aims.

Though video club research first emerged in mathematics education contexts (see Sherin & Han, 2004), a small but growing number of studies document the benefits of video-based professional development to help in-service science teachers develop a vision of and enact more rigorous and responsive science instruction. Clips of classroom interactions in which students and teachers engage in sense-making and argument-building can provide images of this unfamiliar model of instruction and opportunities to obtain feedback from peers on their enactments (Lebak & Tinsley, 2010; Tekkumru-Kisa & Stein, 2015; Zhang et al., 2011). Video-based learning contexts have also supported science teachers to learn to decompose teaching to develop close attention to the complexity of student thinking, to examine how teaching moves inform student learning, and explore differences between tasks that position students as able participants in science practices (Kiemer et al., 2014; Luna & Sherin, 2017; Russ & Luna, 2013; Tekkumru-Kisa, Stein, & Schunn, 2015).

A common feature of these contexts is that teachers engaged in focused, collaborative explorations of science instruction that problematized the complexities of student thinking. These explorations were grounded in making sense of details of students' thinking as they related to developing understanding of content and students' participation in disciplinary practices, the relationship between instructional choices and student learning, and hypothesizing the merits and limits of possible adjustments to instruction (Luna & Sherin 2017; Roth et al., 2011; Zhang et al., 2011). We see these video-based contexts as sites for developing the kind of discourse advocated by Lord and Mason, with video serving as the shared artifact around which teachers can interrogate one another's sensemaking of student learning and instructional effectiveness.

Informed by this line of work, we ask in this study if and how teachers developed a critical discourse of science instruction through focused inquiry and deliberation of teaching and learning. One limitation of existing research on video-based professional development is that it tells us very little about *how* teacher learning evolves through teachers' collective analysis of video (see, for exception, Author, 2008, 2009a). Researchers argue that to better design learning systems we must investigate trajectories of learning within those systems (Kazemi & Hubbard, 2008; Lajoie, 2003). By examining how a group of teachers' conversations change through the types of interactions they have with each other and with video, we gain a deeper understanding of both what and how teachers learn in video-based professional development. Thus, this study investigates both how teachers' noticing and discourse developed as they collaborated with each other to analyze video artifacts over the course of several meetings. We aim to contribute to the growing body of research that documents the value of video clubs for teacher development, as well as a broader line of research that finds that professional learning contexts focused on the teaching and learning process through a critical, inquiry perspective into artifacts of practice can be generative for science teacher learning (Luna & Sherin, 2017; Roth et al., 2017).

Study Design and Method

Study Context

This study took place in the context of a video club that consisted of five secondary science teachers from two high schools from one district (see Appendix A). All had at least ten years of teaching experience and all but one served as instructional leaders in some capacity. The first author had an established relationship with the teachers having taught at North High School for twelve years and worked with them to support science teacher credential students placed at their sites for fieldwork experience. She invited them to participate in a video club because she knew these sites were making early efforts to design year-end assessments aligned with the

NGSS and CCSS. She designed and led five video club meetings once monthly, after school, from January to June, in the participating teachers' classrooms.

The video club design was informed by prior research on video-based learning environments. This research indicates that clips should feature ample evidence of students' reasoning about meaningful science concepts and clip analysis should be supported by tasks and tools that frame and focus teachers' noticing on students' thinking and developing a collective stance of inquiry about what they notice (Author, 2009b, 2015, 2019; Santagata, 2009; Tekkumru-Kisa & Stein, 2017). In the first three meetings, the group collaboratively analyzed published videos (ambitiousscienceteaching.org) that showed images of instruction that reflected a vision of teaching advocated by reform initiatives and featured students engaging in rich conversations to focus attention on students' thinking, with one counter-example (www.timssvideo.com) (Luna & Sherin, 2017). In the final two meetings, the group collaboratively analyzed artifacts from participating members' classrooms to allow the group to see their colleagues' enactments of responsive instruction and examine their efforts to elicit and work with students' ideas (Zhang et al., 2011). When possible, separate samples of student work or screen shots of student work accompanied videos to provide richer insights into students' thinking for further analysis. In cases where video quality was not suitable for analysis, work samples alone were utilized. The first author selected all artifacts for analysis.

During the meetings, just prior to viewing the video together the group responded to the scenario or problem presented to students as featured in the artifact to clarify the goals of the task and situate the analysis in relation to the content of focus (Santagata, 2009). Teachers individually constructed an answer to the problem or scenario presented to the students in the clip and then discussed what they thought constituted an exemplary evidence-based explanation, or "ideal response," to the scenario or problem. For example, they drew how soundwaves would emanate from two different tuning forks (Meeting 3) or wrote a short paragraph explaining the relationship between the length of a pendulum and its period (Meeting 5). They also created a general rubric to characterize high-quality student explanations appropriate for any science discipline.

Finally, to foster a critical discourse, the facilitator encouraged collaborative sensemaking, interpretation of student thinking, evidence-based discussions, openness to multiple interpretations, and problematizing instructional challenges raised in the analysis (Author, 2014; Gröschner et al., 2014). Facilitation choices were driven both by familiarity with the literature on effective facilitation and the first author's experience analyzing video with National Board Certification candidates to focus on student thinking and learning (Author, 2014, Zhang, Lundeberg, & Eberhardt, 2011). For example, the facilitator deliberately *highlighted* noteworthy student thinking in the clip for the group to consider (e.g. "So there are arrows on the inside of the can, but no external arrows"), *prompted* participants to support their interpretations with evidence in the clip (e.g. "Where do you see that in the video?"), *pressed* participants to elaborate on their explanations or offer alternative ideas (e.g. To me, that means amplitude, but, Laurel, you don't seem convinced?) and *revoiced* noteworthy ideas raised by the participants (e.g. "So, you think he's confusing pitch and volume?" (Author, 2014).

Data

Data consisted of field notes, reflective memos, videos, and transcripts of each video club meeting. Informed by the literature on noticing and critical discourse, the field notes captured the nature of teachers' talk and how it evolved over the course of the meetings. During and after each video club meeting, the first author captured the salient ideas participants raised, particularly as they tied to the goals for watching different videos and for cultivating a form of discourse focused on analysis of teaching and learning as represented in video artifacts. While the field notes were informed by this literature, they also captured themes that emerged, ideas for subsequent design of future meetings, and overall impressions of the nature and evolution of the nature of the conversations in each meeting. Memos were written after preliminary coding of the data using existing frameworks to both summarize the nature of the meeting as well as note questions and challenges that arose during preliminary coding to inform the refinement of subsequent coding schemes (Miles, Huberman, & Saldaña, 2014).

Data Analysis

Data analysis was largely interpretive in nature (Hatch, 2002). We started with the literature on teacher noticing of student thinking (Author, 2008; Seidel & Stürmer, 2014) and teachers' critical discourse in professional learning settings (Author, 2011; Lord, 1994) to investigate if and how participants developed both their noticing and discourse practices for analyzing artifacts of teaching. We operationalized critical discourse as highly collaborative (*participation*) discussion of different interpretations of and potential responses to (*stance*) student thinking (*topic*) featured in the clip (*evidence*). Some of these elements, such as *stance*, were adequately measured by an existing framework in the literature (Author, 2009a). Other elements, such as *evidence* and *topic*, required modifications to an existing framework (Author, 2009a), or, in the case of *participation*, an entirely new coding framework to capture noteworthy aspects of critical discourse in this video club context.

In the first phase of analysis each meeting was segmented by activity (e.g. introduction to the clip, analysis of clip, discussion of rubric) for a total of 38 segments across the five meetings. Sixteen of the 38 segments involved analysis of videos and student work and became the objects of further data analysis. The sixteen segments were then divided into idea units, defined by a set of turns at talk centered on a main focus (student thinking about gas laws) or object (students' drawings of sound waves as an assessment) (Schäfer & Seidel, 2015). Five segments from the five meetings were discussed by a research team to gain consistency in identifying idea units. This yielded one to six idea units for each of the 16 artifact discussions, for a total of 54 idea units.

Next, informed by the literature on teacher collaboration (Author, 2012; Horn & Kane, 2015; Lord, 1994), science teacher learning (Thompson, Windschitl, & Braaten, 2010), and teacher noticing in video clubs (Author, 2009a), the first author developed a coding framework through an iterative process, working with a subset of data, to examine both teachers' noticing and the nature of the group's discourse as they analyzed artifacts of instruction (see Table 1). The research team double coded these segments and met to gain consensus on the emergent coding scheme. We then applied the coding scheme to all idea units.

Table 1 here

As we began coding the data, we found that the group discussed several topics together within the main focus, such as *student thinking* about a *disciplinary core idea* as measured by an *assessment*. In these cases, the idea unit was reviewed to identify whether the discussion concentrated on a primary topic or integrated various dimensions of classroom interaction together (see Author 2011, 2017). When several topics were the object of discussion together, we noted the multiple dimensions of focus for emerging patterns.

To characterize how participants interacted with *ideas*, each idea unit was coded for stance and use of evidence. We determined the stance and use of evidence based on the most frequent approach employed by the participants when analyzing artifacts and what they most commonly used as evidence. When participants leveraged multiple forms of evidence, such as science and the artifact, these idea units were double-coded. To characterize how participants interacted with each other, idea units were coded based on how many participants were involved in the discussion, whether their contributions built upon earlier comments or consisted of disconnected, discrete conversations, and whether participants critiqued, expanded on, challenged, or pressed each other's explanations (Author, 2009a, 2012; Grossman, Weinburg, & Woolworth, 2001; Hammer, 2000; Horn & Little, 2010; Lord, 1994).

The fourth phase of coding brought together these four dimensions to develop a sense of critical discourse (Lord, 1994; Mason, 2002). Idea units that integrated several topics focused on the core of teaching and learning, in which participants' comments were also interpretive, grounded in evidence from the artifact or science concepts, and maintained collaborative or critical levels of participation were considered *highly productive*. All other idea units were considered *less productive*. We then tabulated how many idea units met these criteria in each meeting (see Table 2). Finally, we created data representations that represented how topic, stance, evidence, and participation shifted across the five meetings. We were particularly interested in whether teachers adopted a critical discourse about teaching and learning - where they collectively interrogated classroom instruction, with a focus on students' ideas about science, using evidence from the artifacts they analyzed to explore how instructional choices open or close opportunities for learning. We now turn to present our results.

Table 2 here

Results

The central finding is that over the course of the five meetings the group demonstrated elements of critical colleagueship through reliance on evidence to collaboratively interpret student thinking and interrogate problems of practice that arose in their own instruction. Instances of highly productive discussion, both in terms of idea units and turns of talk, increased in Meeting 3 compared to early meetings, then declined slightly in the final two meetings (see Table 2). Further differences are visible in the distribution of topics, stance, use of evidence, and participation across the five meetings (see Figures 1-4).

Figures 1-4 here

Figure 1 shows that the topic of participants' conversation remained primarily focused on student thinking about disciplinary core ideas and instruction throughout the five-meeting sequence. However, later meetings were characterized by a more integrated discussion of topics. In terms of stance (see Figure 2), participants adopted a primarily evaluative stance in early meetings but shifted to become more interpretive in Meeting 3, then adopted a balanced stance of interpretive and evaluative comments when examining artifacts from their own classrooms in later meetings. Participants' use of evidence shifted over time (see Figure 3), beginning with a mixture of evidence in early meetings, almost exclusively using artifact-based evidence in Meeting 3, and then incorporating a mixture of evidence from the artifact and anecdotal evidence based on their professional experience when viewing video from their own classrooms. Participation varied in the early meetings (see Figure 4). Though there was evidence of critical and collaborative conversations, later meetings included more instances of conversations with single participants leading the discussion than in earlier meetings.

As we review these elements together, we identify three phases of discourse that emerged as the group analyzed first others' and their own instruction – shifting from more simplified analyses of teaching in meetings 1 and 2 (Phase 1), to more sustained, inquiry-focused discussions in meeting 3 (Phase 2), then explorations that problematized teaching and learning in meetings 4 and 5 (Phase 3). Below, we explain how the elements of critical discourse - topic, stance, use of evidence, and participation - coordinated differently in the three phases..

Phase 1 Discourse Pattern: Interpretation and critique of student thinking and general teaching strategies based on anecdotes

Meetings 1 and 2 were characterized by two types of discourse patterns. One pattern focused on a descriptive and interpretive approach to analyzing student thinking about disciplinary core ideas or efforts to understand the disciplinary core idea itself. The second, more prevalent, pattern was characterized by an evaluative stance to analyzing student thinking and teaching. More specifically, the teachers drew on general teaching scenarios or anecdotes from their own instruction to critique what they observed. For the most part, the conversations were collaborative in nature, though there were some segments of talk when one or two teachers dominated the discourse.

We provide an example from Meeting 1 to illustrate the interpretive discourse segment of the meetings. In this example, the group examined two different video clips featuring students' models to explain why a tanker truck that had been steam cleaned and sealed shut collapsed. This clip was selected because it illustrated a disciplinary core idea about gas laws – specifically, the relationship between temperature, pressure, and volume – and featured teaching practices that elucidate students' evolving thinking and reasoning. The excerpt shows students describing and interpreting their drawn models, depicting the gas molecules and forces inside and outside the tanker before, during, and after the collapse. The facilitator launched the conversation by highlighting arrows in a student drawing, followed by teachers' comments.

Mitch	I thought this would happen. Look at the arrows on the bottom drawing. So, these kids are trying to explain why it bent where it bent.
Vince	Ahh, yeah.

Mitch	So, I thought about that… I thought they're going to have some crazy side conversation about why some parts of the tank were so weak and they're going to go off on a total explanation of there are seams in the thing that are way weaker than other seams and so they're going to stray away from-
William	-That might be the case.
Mitch	Yeah.
Facilitator	Well her arm is kind of obscuring it, but you see, it doesn't look like the arrows are different lengths in the middle diagram. If she moves her arm, maybe we can get a better look at it. But there's no arrows, right now, in the top diagram.
Vince	Yeah.
Mitch	Yes.
William	If you look at the bottom ones, there's more big arrows in the bottom one, like there's more pressure on that side. But then again, those arrows, to me, it seems like the kids are identifying length of pressure, or pressure amount to length of arrow, where we were thinking about length of arrow is how fast it would be.
Mitch	Well that's the forces…. The common misconception here is that something is pulling in from the inside. Something's happening on the inside that's pulling the tanker closed. And that's the misconception. That's the really tough sell – it's that the forces are greater on the outside than on the inside. That's what causes the implosion.
Ron	Right.
Mitch	They think something has to be pulling it from the inside.

This conversation represents the teachers' engaging in evidence-based analysis of student thinking early in the meeting. Mitch noted the location of the arrows on the bottom diagram and interpreted what the arrows meant about students' ideas regarding the forces working on the tanker. The facilitator returned attention to the drawing, highlighting another feature of the students' model, namely that the students did not represent unbalanced forces with the arrows in one of their drawings. William then took up this idea by noting another feature of the students' model, specifically the size of the arrows, and wondered what information the arrows were supposed to convey. Mitch added to this interpretation and connected what the group saw in the drawings to Vince's "ideal response" constructed prior to watching the clip. These cycles of describing and interpreting student thinking were typical of the opening interpretive sequences across all meetings, suggesting that the teachers entered the video club with a disposition to make sense of student ideas.

Though teachers engaged in critical discourse focused on student thinking for portions of these early meetings this was not the dominant discourse pattern – of the 19 idea units from meetings 1 and 2, only two were characterized as highly productive. The more common discourse pattern was one in which the participants commented on the *correctness* of the student ideas and the effectiveness of the teachers' moves to respond to students' ideas in the clip. In nearly half of the total turns in these two meetings, the topic of the discussion centered on instruction and/or student thinking as evidenced in the artifact, but the stance was evaluative in nature. Evidence from the artifact served as a launching point for discussions about general teaching moves one *should* employ when working with students' ideas and often shifted to *general* recommendations based on anecdotal evidence. Of the 19 idea units from the two meetings, 12 included evaluations involving instruction and eight of those relied on some anecdotal support, what we characterized as less productive.

The following example illustrates this discourse pattern. This exchange occurred after watching the teacher press students to explain more about their before, during, and after drawings of the tanker truck collapse. After spending time as a group interpreting what the students' changing models revealed about their understanding, Mitch launched a discussion about a tension he experienced when trying to lead students to “correct” ideas without “giving too much away” in the limited instructional time available in a lesson. He commented:

> The teacher’s role is interesting…You want to restate their process so that…you’re fostering their ability to come up with it. And in that moment whenever I have those discussions like, you’re always scared you’re going to give too much away. And you’re so tempted! You’re like looking at the clock, you’re thinking about the lunch bell… I could just make this happen!

Mitch pointed to a general teaching dilemma that he experienced when deciding to move on under time constraints while honoring students’ process for developing their ideas. This tension is not unique to this lesson and could have taken place after many of the clips featured in the video club. William acknowledged this tension by adding a comment based on his experience:

> You have to skirt between, like brush, the frustration point ... And sometimes when you go too fast and it’s just like…almost like playing with it, you gotta play with it. Like just a little, like tease ‘em enough. But don’t go overboard because they’ll stop.

Both teachers’ comments implied that there was a “correct” way to go about managing this interaction: afford students time to puzzle over problems rather than giving them the answer right away but pull them along before they get frustrated or time runs out. Though focused on the relation between student thinking and instruction, the “fix-it” approach to this dilemma marks this as an evaluative response based on a professional anecdote and not on interactions they observed in the artifact, or that were particular to students’ understanding of the content.

Similarly, in Meeting 2, Mitch and Ron used an evaluative stance to critique the way the teacher in the second clip set up the students’ investigation of mechanical advantage using pulleys, masses, and spring scales. Mitch and Ron remarked that the lesson was “chaotic” and “at this point in the lesson [the teacher’s] not able to even figure out what their experience is with the ideas.” Though there was concern about the lack of access the teacher seemed to have to students’ understanding of the disciplinary core idea, their critique lacked specific evidence about the *content* of students’ ideas. They followed this critique with general suggestions to give clearer directions and divide the lab tasks differently because, in their professional experience, that approach is "more effective." General suggestions of this type could apply to almost any clip explored in the video club. Both suggestions inferred that there was a "right" and a "wrong" way to go about the activity featured in the clips, without delving into the complexity of what these approaches might afford or limit for students and were, therefore, less productive.

Phase 2 Discourse Pattern: Sustained collaborative inquiry into the instructional triangle

Meeting 3 marked a distinct shift in the discourse, in which participants' talk remained largely descriptive and interpretive and focused on evidence from the artifact to make sense of student thinking. Of the 20 idea units in Meeting 3, 10 focused on student thinking about disciplinary core ideas, and an additional four idea units focused on student thinking about disciplinary core ideas combined with elements of instruction or assessment. That is, in four of the 20 ideas units, they considered how the task prompt or their questioning provided insight into student thinking – a marked increase compared to Meetings 1 and 2. The remaining six idea units were isolated discussions about assessment, the disciplinary core idea, or students' use of science vocabulary – all components central to the teaching and learning process. Of the twenty idea units from this meeting, 12 were considered highly productive.

In Meeting 3, participants' talk was less evaluative and largely interpretive, with long sequences of the group engaged in collective sense-making of teaching and learning. Evaluative idea units averaged nine turns at talk compared to 31 turns at talk for descriptive and interpretive idea units. There was only one idea unit coded as having "single" participation in this meeting.

The following excerpt illustrates the dominant form of talk in this phase of the meetings. The first clip the group watched in Meeting 3 focused on students' written and oral explanations for what sound waves would be generated by two different tuning forks. The facilitator launched a discussion of this first video with a question referring to the discussion the group had about what would be the “ideal response” prior to viewing the clip. The group established that students could depict compression waves emanating from both tines of the fork, with the larger, lower-pitched fork producing waves that are more spaced out (lower frequency) and the smaller, higher-pitched fork producing waves that are closer together (higher frequency). Assuming both forks were struck with the same intensity, the amplitude, or size, of the waves should be equal.

In this sequence, participants collaboratively described, interpreted, and responded to student ideas about sound using specific evidence from the clip. William noted “I see more lines in the high pitch than I see in the low pitch.” Vince added “On one side, like on the low pitch side, there seems to be more space there compared to the left-hand sides. The ones on the right are closer together than the ones on the left.” William then conjectured what these details might mean about the students’ understanding about pitch and volume, suggesting that it was unclear if the student understood that low pitch did not always mean low in volume as well. Interactions with multiple participants making sense of student ideas were typical in this meeting.

In four of the 20 idea units, the group continued to elaborate on the analysis of student thinking to consider what kinds of questions they might pose to get further insight into student thinking. Continuing with the example above, William wondered aloud “but if I ask him which one would be a higher volume, essentially, they would both be the same volume, at the same distance, right?” Ron confirmed that, according to their “ideal response” conversation earlier, that the forks should have the same amplitude, or volume, at the same distance. William then concluded, “then that’s a good question I would ask the student” because it would make clearer what the student thinks the spacing of lines in his drawing actually represents.

This interaction with the artifact differed from Meetings 1 and 2 in that the groups' response to the artifact marked an integration of pedagogical practices informed by analysis of student thinking related to the disciplinary content of the lesson. The instructional dilemma and proposed solution were specific to the dilemma and integrated elements of the student's understanding of a disciplinary core idea, as well as a specific response to the students' idea.

The nature of participation in this meeting also differed from Meetings 1 and 2. The three teachers who attended this meeting contributed in the examination of the artifact, even though neither William nor Ron taught sound in their respective courses. In addition, Vince, noticing that one student's intricate dot work demonstrated how individual particles behave in sound waves, took the initiative to raise an artifact for discussion, unlike in previous meetings in which the facilitator directed the group to consider student work samples for analysis, further demonstrating attention to and interest in student thinking.

The combination of attending to the relation between various dimensions of the instructional interaction, using the artifact as evidence, and the increased collaboration and initiative by different group members demonstrated that this group had constructed and sustained a more critical discourse to notice salient details in the artifacts and to press each other to further elevate the quality of the discussion.

Phase 3 Discourse Pattern: Problematizing own instruction

Meetings 4 and 5 marked a shift in the video club design, with the group now viewing artifacts from the participants' own classrooms to examine teachers' experimentation with responsive practices to center student thinking. A noteworthy feature of the discourse in these meetings was that the description and interpretation of student thinking about disciplinary core ideas was followed by a discussion of teaching practice. However, participants now frequently problematized rather than critiqued instruction. Participants relied again on anecdotes from professional experience, but an important distinction in Meetings 4 and 5 is that these anecdotes were used to inquire about how to improve their own teaching rather than normalize generic problems of practice.

Similar to Meetings 1 and 2, participants spent a large proportion of meeting time discussing instruction related to student thinking (eight of the 15 idea units) rather than interpreting student thinking about the disciplinary core ideas (three of the 15 idea units). Comparable to Meetings 1 and 2, a large portion of the idea units were evaluative (seven of the 15 idea units). Additionally, the conversations were a mix of collaborative and individual talk, with 21% (four of the 10) of the idea units coded as single or parallel participation in Meetings 1 and 2, and 20% (three of the 15) coded as single participation in Meetings 4 and 5. Thus, four of the 15 idea units were considered highly productive.

We provide an example here to illustrate the ways the teachers problematized instruction in the final two meetings. In Meeting 5, the group examined artifacts from a two-day lesson from Mitch's classroom on pendulums. The first day was spent learning how to use the apparatus and to identify through observation that the only variable that influences the period of a pendulum's swing is the length of the pendulum. The following day, Mitch charged his students with collecting data and graphing 10 different pendulum lengths of their choice and orally reporting their results to the class. The students were also asked to circle the mathematical function that best represented their data and compose a written explanation of what they noticed about the relationship between the period and the length of the pendulum.

After first examining a video clip and two student work samples from the Day 2 activity, Mitch introduced a third work sample for examination. He noted that while many students identified the "basic relationship" that the shorter the length, the shorter the period, this particular group wrote "the shorter the length, the shorter the period, so therefore the higher the string is held, the longer it will take." He noted that the students started with the correct relationship, but in their attempt to clarify their answer, they mentioned something that was not in their data — string height — and that this addition was incorrect because amplitude has no influence on the period. The group discussed what students really meant by "the higher the string is held" and argued alternate possibilities besides amplitude. This description and analysis of student thinking in the artifact then led to questions about the instruction and task design. Mitch began the discussion by wondering about the quality of the prompt and the difference between medium and high-quality responses. The following discussion ensued:

Mitch	Is there a difference between medium and high quality in this prompt?
Facilitator	Does the prompt afford that? I don't know. I think that what is really tricky is a lot of what we get from the students hinges on how the prompt is crafted. Sometimes it's not even the phrasing of the question, it's like…they're engaging in the wrong task.
Laurel	Yeah.
Mitch	You can see that I changed the prompt, right?
Laurel	Yeah.
Mitch	So now it makes sense because I wanted it to be more about the line matching, so I changed the prompt to say which one of these looks like a match to what you are seeing. I could have asked for more detail there, but this class probably needed just the idea of the relationship of the longer length to longer period. I wanted to get into a discussion about - is it this one or is it this one [pointing to linear and log graphs]?

In this exchange, Mitch shifted the discussion about the students' understanding of pendulums to the design of the prompt, questioning if the way he worded the prompt provided enough stimulus for students to identify the logarithmic pattern as the matching function for this relationship — a function that Mitch explained that he wanted students to understand when discussing the "ideal response" earlier in the meeting. Rather than offering simplistic solutions to this instructional dilemma as he and others did in early meetings, Mitch instead asked a question about the prompt design and how to balance competing instructional priorities – what we came to understand as problematizing instruction to move learning forward rather than a simplistic evaluation of a teaching situation.

Also typical in Meetings 4 and 5 were extended segments of participants wondering aloud about instructional challenges they faced when enacting instruction to elicit students' thinking. For example, in Meeting 4, the group analyzed samples of student work from William's chemistry class about gas laws. There was extended debate about one student's use of dots and arrows to represent the movement of gas and pressure and what the student was attempting to convey about pressure, volume, and temperature. Mitch commented, "How do you encourage students to draw things that don't leave us with questions?" This was followed by William, Mitch, and the facilitator puzzling through possible teaching actions. William talked through these options for several turns of talk then mentioned how he might be able to leverage a practice he had seen his students engage in spontaneously:

William	I noticed that kids only get one chance to get this done. Right?... But I've noticed some kids videotape on their smart phones and go back and look…
Facilitator	Really?!
William	Yeah…not all eight groups but there would be like one or maybe two groups that would do that…Maybe if I did a better job of telling them, use your camera to record and then go back and re-visit, then that would be better.
Facilitator	Because that's data right there.
William	Right. Because how are they supposed to think about it when they don't see it again? When you come around and they know they're not there, watch it again.

In this example, William considered how he might allow students to use their phones to allow them to further think through the content of the lab using close observations. This example illustrates how the teachers problematized and proposed next steps in teaching in these later meetings in ways that were tied to advancing student thinking, rather than offering quick solutions to get students to a particular answer. We see these examples as illustrative of a shift in professional discourse, with the group adopting a critical, inquiry stance to problematize and make sense of teaching and learning.

Discussion & Conclusion

Two decades ago, Lord (1994) introduced a model of professional learning to accomplish reform efforts. Science educators find themselves in a similar moment of reform today, with the adoption of new content standards and a national framework that attempts to redefine teaching and learning of science. Despite extensive research documenting elements of “effective” professional development (e.g. Garet et al., 2011), the field continues to struggle to support teachers enacting responsive forms of science instruction. Because of the simplicity of the video club model, teachers’ ubiquitous access to tools to capture and share video, and the widespread adoption of professional learning communities as contexts for teacher learning, we proposed that a video club model would move professional conversations closer to those Lord envisioned. Results from this study suggest a video club can advance this aim. By starting with videos rich in evidence of students’ reasoning that painted a vision of what type of learning and instruction was possible, then turning the lens on their own classrooms, this group questioned their understanding of science concepts, used evidence to support interpretations of students’ thinking about science, and thoughtfully questioned their attempts to enact more responsive instruction.

Prior research finds that teachers are less inclined to attend to student thinking without being prompted to do so (see Author, 2008; Johnson & Mawyer, 2019; Santagata, 2009). This group, however, started with and continued to focus on student learning over time. Importantly, they shifted in how they made sense of student thinking. Early on, they viewed student thinking as isolated from teaching and shifted to understand that what students thought about the content was very much tied to elements of teaching – to tasks, questioning, and assessment.

Other research advocates for instructional decisions to be informed by analysis of artifacts (Yeh & Santagata, 2015; Tekkumru-Kisa & Stein, 2015). The literature also suggests that teachers have a wealth of professional knowledge that can inform instructional decisions (Cochran-Smith & Lytle, 2009). We theorize that both forms of evidence functioned to support the group's discussions, particularly as they shifted from identifying quick fixes to seeing the complexity in teaching and learning that needs to be problematized to improve.

Finally, we found that collaboration varied over time. Early on, when watching video of others, they collectively constructed explanations and interpretations of what they observed. However, when they shifted to watch their own video, they became less collaborative, particularly related to problematizing their instructional choices. Because the group only shared videos in two meetings, they may not have yet developed norms for critically analyzing colleagues' practice (Author, 2008; Coles, 2013). Though this group had collaborated extensively prior to the video club around curriculum and assessments, what they had not done was view each other teaching – either in real time or with video. Thus, it could be difficult to offer suggestions around each other's videos because they may not want to be viewed as critiquing a colleague (Cohen & Ball, 1999). However, it should be noted that individual moments of problematizing teaching were preceded by collaborative analyses of students' disciplinary thinking. We conjecture that collaborative moments of unpacking student thinking were necessary to achieve the level of individual inquiry in their own teaching.

We now turn to offer some beginning explanations about how the video club design supported the development of a critical discourse, recognizing that additional research is needed to empirically advance our conjectures. First, the structure of the video club held participants accountable for leveraging evidence in support of claims and, when featuring their own instruction, for attempting to enact incremental changes in practice. Two teachers experimented with practices to elicit student thinking and shared these attempts with the group (Author, 2018). The group applauded their efforts, but also provoked consideration about how to advance student learning by analyzing instruction in relation to what they observed about students' thinking. The video club also provided a supportive structure for analyzing the impact of instruction on student learning as it was enacted. The group often spent 10-20 minutes discussing two to five minutes of thoughtfully chosen video. The ability to slow down teacher decision-making and to be able to leverage the knowledge of other educators was a powerful affordance of video-based professional development (Sherin, 2007).

Another feature was sequencing clips from others' classrooms and then videos from the participants' own teaching. Providing teachers opportunities to decompose core dimensions of ambitious teaching represented in others' classrooms may have served to provide a model for enactment (Author, 2015, 2017; Cobb, 2017). An important area for future inquiry concerns what aspects of ambitious teaching participants took up in their practice and whether the videos of others provided representations to support those experimentations.

A third feature was the integration of student work samples with the video. Research identifies features of clips that influence the quality of discussions (see Author, 2009b). Less is known about how different artifacts serve to support learning. It may be that the inclusion of copies of the student work samples featured in the video clips helped the group reference specific details to further advance their analyses and interpretations of student thinking. This suggests that the video worked in tandem with the work samples to paint a more complete picture of students' thinking. Future exploration is needed to understand how different artifacts coordinate and how teachers and facilitators leverage them to elevate video discussions (see Coles, 2013).

Though the findings offer promise for video-based professional development supporting science teacher learning, we also recognize limitations to the study. First, participants in this video club were experienced and accomplished teachers who volunteered to participate to improve instruction and who had prior experience collaborating with each other. An important question concerns how these experiences may have supported their conversations early in the video club. Another limitation is the group did not have opportunities for iterative cycles of enactment and analysis of each other's practice. We saw the group focus more squarely on the artifacts in Meeting 3, and then move to anecdotal evidence in Meetings 4 and 5 when they began watching video from each other's classrooms. More research is needed to explore when reliance of professional anecdotes is productive for analyzing teaching and when it is more productive to stay grounded in the artifact. Finally, we originally sought to replicate prior video club studies to provide empirical evidence that this model of video-based professional development can result in teachers achieving the vision of reform. However, like others (see Borko et al., 2011), we adopted the video club to respond to teachers' local needs. Recent research offers models for community-engaged scholarship, that show promise for supporting sustained enactment and transformations in education systems (Fishman et al., 2013; Penuel & Fishman, 2012). A potentially fruitful direction for video research in professional development concerns how collaborations of this sort can elevate the potential of leveraging video in professional learning and for developing teacher leaders who can support teachers' productive inquiry into teaching and learning to achieve the vision of a responsive form of science instruction.

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Appendix A

Study Participants

Participant	Campus	Degrees & science background	Course(s) taught	Years teaching experience	Leadership experience
Ron	North HS	BS biology MA Public Health	Biology, Honors Biology, Anatomy & Physiology	12	mentor teacher
Mitch	North HS	BA liberal studies (geology, music, French)	Earth Science, AP Environ-mental Science, Physics	20	mentor teacher; department chair; director of internship program at JPL
Vincent	North HS	BS geology MA teaching science (physics)	Physics, AP Physics	15	mentor teacher; former department chair; Science Olympiad advisor
Laurel	South HS	BA Spanish, biology, & education MA education PhD education (astronomy education & educational technology)	Earth Science, AP Environ-mental Science	15	adjunct professor for science credential students; National Board Certified Teacher
William	South HS	BS chemistry MA education (in progress)	Chemistry, Honors Chemistry	10	

Table 1

Video Club Coding Framework

Dimension	Code	Description	Example
Topic	Instruction & Curriculum	Teaching moves, task design, materials used, descriptions or analysis of teacher-student interactions about the science content; teacher primary focus.	So when you're walking around you ask questions, like, "Well now are these dots and arrows representing water or the gas?"
	Classroom management	How teacher addresses distribution of materials, student behavior, and transitions between tasks.	She spent a lot of time with that group and I'm not sure I'm comfortable spending so much time with just one group.
	Student behavior	Student actions disconnected from thinking and reasoning.	I don't understand how that teacher can tolerate that kid yelling.
	Classroom climate	Norms for participation in the classroom, including roles, expectations, and participation.	In some classrooms, that's a complete shift. And that means the teacher is going to with a microscope look at what I'm writing and can I really describe ideas. When you're a teacher doing that it's a different job than just saying, "you get five points out of five."
	Assessment	Measurement of student thinking and skill development.	My impression is he's on the right track and maybe he just needs a little more to be higher quality. For example, if he was consistent with the lines like in the fork on the right.
	Student thinking	Students' approaches to tasks and problems; ideas students convey through speaking or writing.	See, it says "you place it in cold water and it popped. It smashed."

	Disciplinary Core Ideas	Science concepts, not including discrete skills such as measurement, computation, equipment use.	Something's happening on the inside that's pulling the tanker closed. . . the forces are greater on the outside than on the inside. That's what causes the implosion.
	Motivation	Students' interest and persistence.	They lack the discipline and the desire to push things through, the "stick-with-it-ness."
	Academic vocabulary	Students' acquisition and use of academic vocabulary.	Because our students, they're not armed with appropriate vocabulary yet.
	Video	Authenticity of the video clip.	Are they doing it just because the camera is there, and they're forced to be thinking?
Stance	Evaluative	Simplistic, judgmental assessments of teaching or learning.	I thought her comeback to the large versus small molecule point was a weakness.
	Descriptive	Detailed observations and thick description of teaching and learning.	I notice she has the spacing here about the same, but you don't see as many dots being compressed here. Some of the energy from that sound will dissipate.
	Interpretive	Problematizing teaching and learning by asking questions and attempting to understand the underlying science ideas.	Well, I think, because this person drew arrows in the can, and now the person drew dots in the can, they understand that the gases have slowed down inside the can.
Use of Evidence	Anecdotal	Based on personal experiences as learners or teachers.	I know that my students might know the answers but when they're in front of a group they're just terrified that they're going to say the wrong thing.

	Artifact	Based on the shared artifact.	I noticed just noticed that too – the cymbals, there's a there's lot of lines, and then the bass drums have more space between them.
	Science	Based on science knowledge/theories.	I like to imagine that because we're in a soup of air particles that's very thin and if you push something, something else will be affected over there.
	Artifact/Anecdotal	Based on a mixture of evidence from the shared artifact and personal experiences as learners or teachers.	When you look at it, they are drawing these sound waves. Like this [gestures]. You know, I would not have drawn all these [gestures] compressions.
	Artifact/Science	Based on a mixture of evidence from the shared artifact and science knowledge/theories.	I would love it if a kid would say at this point when she says what's the other evidence you see of energy being used up or energy change, right? Well evidence of energy change is the temperature of the warm water going down. That's energy that has left the system into the flask.
Participation	Single	One member dominates discussion.	
	Parallel	Two or more members participating equally, but discrete, serial, or parallel conversations.	M: I don't think it was an accident, you know. It's like here's an old car and we can experiment with it. W: The kids have a possible enemy when you're steaming. It has to be open to steam…So that's the important point those hot gases expand and kick some of those small gases out.

		M: I thought her comeback to the large versus small molecule point was a weakness.
Collaborative	Two or more members participating in ways that build upon each other’s contributions with instances of cooperative overlapping talk.	F: So I think compared to the top drawing you would want to see a change in the shading, right? R: Mmm hmm. W: I can’t tell a difference though. R: I can’t either. I see bigger smaller but- W: - I see there’s some gaps now in between the answer but, yeah. V: But it would even be hard to draw.
Critical	Two or more members participating in ways that build upon each other’s contributions, challenge each other’s interpretations and practice, with instances of cooperative overlapping talk.	L: If they don’t know force diagrams I can see them putting arrows in opposite directions and not quite understanding those cancel out. V: I’m sure they probably had kinetic molecular theory prior or something. W: Well, I dunno. When I teach this I just tell the kids about temperature being speed, right? But then pressure is the collisions, so. I mean I never thought about this might be an issue.

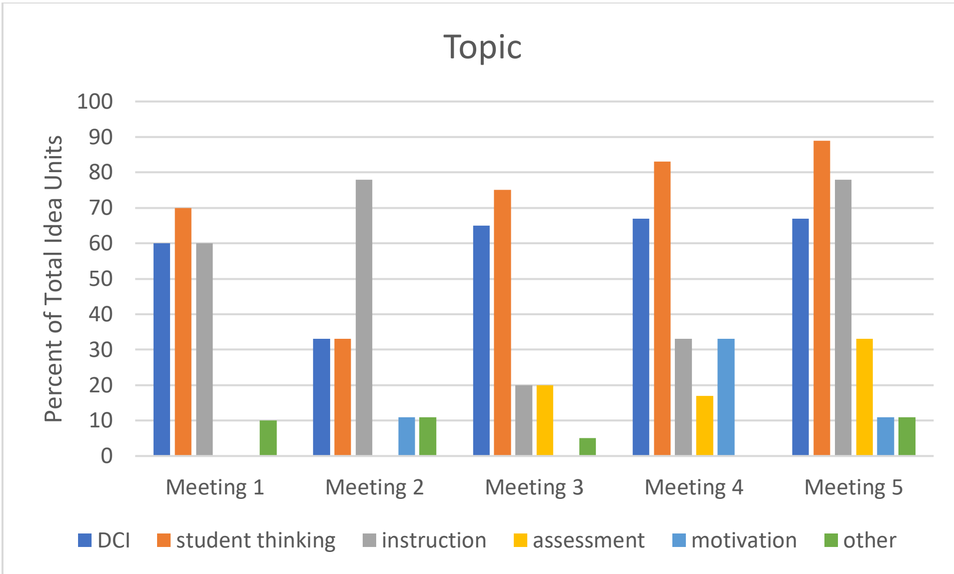

Figure 1. Shifts in topic across the five-meeting sequence.

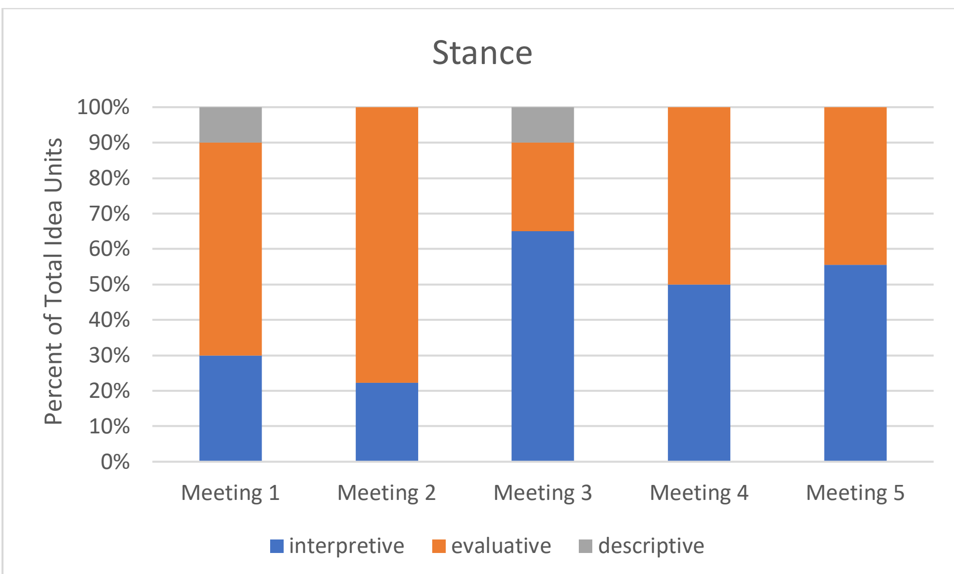

Figure 2. Shifts in stance across the five-meeting sequence.

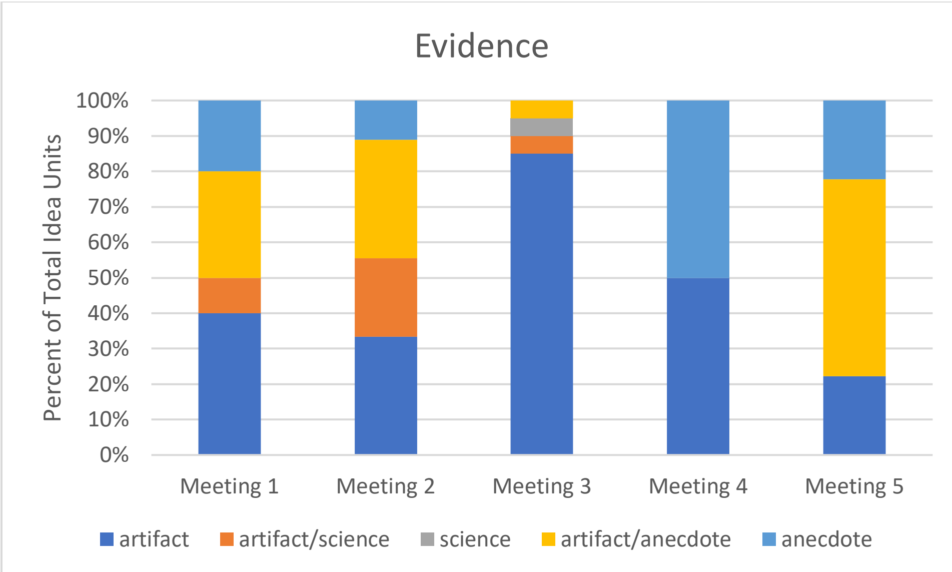

Figure 3. Shifts in use of evidence across the five-meeting sequence.

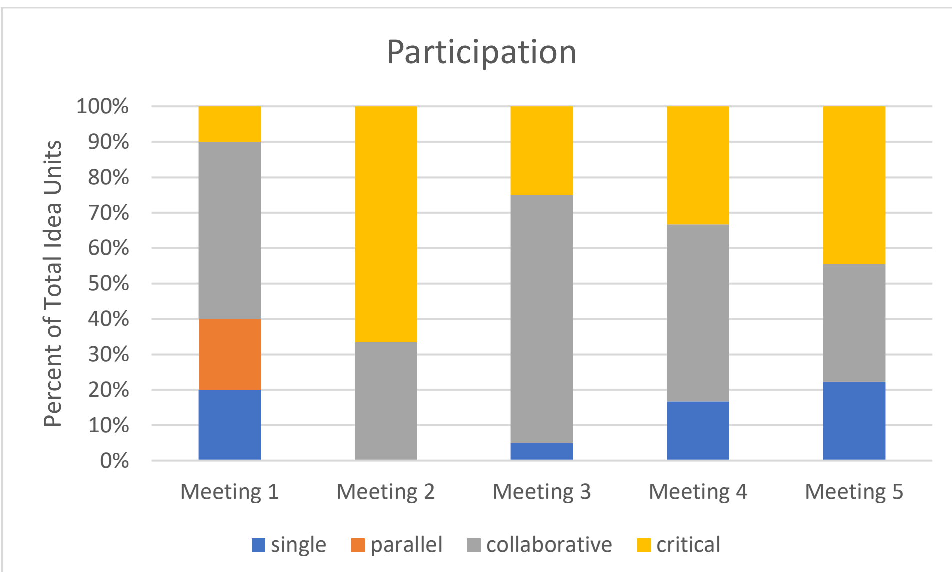

Figure 4. Shifts in participation across the five-meeting sequence.

Table 2

Occurrence and length of idea units across the five-meeting sequence

	Meeting 1		Meeting 2		Meeting 3		Meeting 4		Meeting 5	
Productivity	Highly	Less	Highly	Less	Highly	Less	Highly	Less	Highly	Less
Total idea units	2	8	0	9	11	9	2	4	2	7
Total turns of talk	72	177	0	365	369	153	92	127	77	154