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Tara Barnhart
Chapman University, tbarnhart@chapman.edu

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Examining an Activity System of Learners, Tools, and Tasks in a Video Club

Tara Barnhart
Chapman University

Introduction

A common emphasis in new science frameworks and international measures of students' science achievement is the need to integrate understanding of science concepts with the practices of science. Specifically, students should know how to construct and interpret scientific explanations of everyday phenomena from evidence (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; National Research Council [NRC] 2012, 2015; OECD, 2018). The connection between the products and processes of science should be explicitly supported through instructional practices (Krajcik, McNeill, & Reiser, 2008; NRC, 2012). This instructional shift demands a different type of classroom discourse, one where students' ideas are the center – what Windschitl and colleagues term Ambitious Science Teaching (Windschitl, Thompson, Braaten, & Stroupe, 2012). It also requires a shift in the role of the teacher from a transmitter of a cannon of knowledge to one who mediates students' reasoning (Hammer, Goldberg, & Fargason, 2012).

One skill that is integral to instruction centered around students' thinking is attending to, interpreting, and responding to students' thinking, a cluster of skills referred to as noticing (Luna & Sherin, 2017; Mason, 2002; Stroupe, 2014; Thompson et al., 2016). Video clubs, in which groups of teachers meet to analyze recordings of classroom practice, have been shown to be effective in supporting teachers in developing noticing of students' ideas and adopting an interpretive lens to make sense of students' ideas (Johnson & Mawyer, 2019; Luna & Sherin, 2017). However, simply gathering teachers together to analyze videos of teaching is not sufficient for changing either noticing or instruction (Blomberg et al., 2014). Video clubs must intentionally utilize tools, tasks, and talk to promote changes in teachers' noticing of student thinking (van Es & Sherin, 2006). This chapter describes the design of one such video club of secondary science teachers and examines how different artifacts of practice, tasks to frame the participants' attention on students' thinking, tools generated from those framing activities, and facilitation moves coordinated to promote an inquiry stance into science teaching practice.

Design Features of Video-based Professional Development

Because teaching is a complex practice, it is important to provide both a tangible vision of desired practice and ways to rigorously decompose it to study and refine it (Grossman, Hammerness, & McDonald, 2009; Hammer & van Zee, 2006; Windschitl, Thompson, Braaten, & Stroupe, 2012). Video has proven to be useful for providing authentic models of ambitious practice, opportunities for teachers to systematically analyze the relationship between instruction and student learning, and support enactment of student-centered practice in science (Hougan et al., 2018; Luna & Sherin, 2017; Roth et al., 2011; Stürmer, Könings, & Seidel, 2013) in ways that reflection based on recollection do not (Rosaen et al., 2008). Notable across this work is the importance of matching both the type of video and facilitation of discussion around the video with the goal of the professional development (van Es, Tekkumru-Kisa, & Seago, in press).

Video has affordances that can greatly influence teacher learning in professional development settings if used intentionally. Because video can be slowed down and re-viewed multiple times it has been used to establish a vision of ambitious teaching (Levin, Hammer, Elby & Coffey, 2012; Hammer and van Zee, 2006) as well as to model how to analyze teaching challenges in authentic classroom settings (Zhang, Koehler, & Lundeberg, 2015). With the growing emphasis on instruction centered around students' ideas, video is increasingly used to provide opportunities to learn to notice students' thinking – specifically how to attend to and reason about students' ideas and consider how these ideas should inform next teacher moves (Jacobs, Lamb, & Phillipp, 2010; Yeh & Santagata, 2015). Each of these components of noticing (attending, analyzing, and responding) are inter-related but separate skills that can be developed with video-supported practice that permits the slowing down and decomposing of the frenetic classroom environment (Barnhart & van Es, 2015; Santagata & van Es, 2010; Seago, Koellner, & Jacobs, 2018).

For vision-setting, working through problems of practice, and noticing students' ideas, clips are most impactful if they closely resemble the viewer's own classrooms (Kleinknecht & Schneider, 2013; Zhang et al., 2011a). Sherin and colleagues (2009) identified three additional features of clips they used to specifically hone teachers' noticing of student thinking: windows into student thinking, depth of student thinking, and clarity of student thinking. Windows into student thinking can include multiple sources of evidence (written, verbal, or signaled) that provide insights into how students are reasoning. Low windows indicates "little evidence of student thinking from any source" whereas high windows indicates "detailed information from one or more sources," (Sherin, Linsenmeier, & van Es, 2009, pp. 216). Depth of student thinking reflects the richness of the mathematical idea – is it a task that is routine and recall-based (low) or does the student engage in conceptual reasoning (high)? Finally, clarity of student thinking reflects how easy it is to make sense of a students' response. Clips that feature responses where the students' thinking is obvious are high clarity, clips that feature responses that are ambiguous or that require a great deal of interpretation are low clarity. Sherin and colleagues (2009) found that clips featuring both high windows and depth sustained productive conversation regardless of the clarity of the thinking.

Whether the video is of oneself or others also influences what participants notice and feel in video-based professional settings. Seidel and colleagues (2011) found that teachers who had previous experience with video noticed more components of teaching and learning and reported the experience to be more motivating and relevant to their own teaching practice compared to those who watched videos of others. Teachers who watched their own videos were less critical and considered fewer alternatives in their analysis of their own videos. Their recommendation, if the focus of the video work is on student thinking, is to start with teachers examining their own videos to build experience with video, provide a student focus, and hone their noticing on certain details of learning and teaching. Somewhat differently, Kleinknecht & Schneider (2013) found that teachers who watched their own videos attended more to student learning however, teachers who watched others' videos conducted deeper analyses, and considered alternative actions the teacher could have taken more frequently. Their recommendation, if the purpose of the video work is to promote rigorous reflection, is to start by watching videos of other teachers in similar teaching assignments to their own.

The quality of the clip notwithstanding, it cannot be assumed that even veteran teachers will notice the salient features of what makes instruction effective without support (Prusak, 2015; Sherin & van Es, 2009). Both the selection of clips and the form support takes to notice specific features of the clips should depend on the learning goals of the participants in professional development (Borko, Koellner, Jacobs, & Seago, 2011; Seidel et al., 2013). One particular mode of support that has been noted by several researchers over the past decade is facilitation of discussion around video. Zhang and colleagues (2011b) identified patterns of facilitation moves that enabled or limited engagement and idea progression around learning issues related to instruction. Although *questioning* and *revoicing* were the facilitation strategies used most often by the group facilitators, they were not always used in ways that built upon on teachers' ideas or sustained group attention to a topic aligned with the professional development goals. When *questioning* and *revoicing* were used to encourage the teacher participants to elaborate on and explore their ideas, discussions were more productive. Relatedly, Coles (2013) identified five key aspects of working with teachers using video: selecting the clip, setting up discussion norms, re-watching the video clip, moving to interpretation, and metacommenting. These aspects, or decision-points, were used in ways that were more or less productive when considered in relation to the participants. Facilitator choices around these five aspects that encouraged teacher participants to consider new interpretations of classroom events and new patterns of instruction were more productive than choices that allowed basic generalizations and evaluations of practice. Similarly, van Es and colleagues (2014) describe a set of facilitation moves organized around four main practices: orienting group to the video analysis task, sustaining an inquiry stance, maintaining a focus on the video and the mathematics, and supporting group collaboration. They identify the similar and different ways facilitators of two video clubs coordinated moves to respond to the different goals of each video club design, whether they were to attend to and interpret students' mathematical thinking or how a teacher might respond to students' understanding of linear functions. Lesseig et al. (2017) also identified how facilitation around framing questions changed as professional development goals were refined.

Common across these studies is the need to move beyond the identification of facilitation moves and clip features and explore in greater depth how facilitators make choices about enacting these moves in relation to the affordances of the clips, the contributions of the participants, and the goals of the professional development. van Es, Tekkumru-Kisa, & Seago (in press) advocate for treating the elements of video-based teacher professional development programs as activity systems to better analyze and understand how the various elements interact to support teacher learning. When studying an activity system, one accounts for how participants, the tools, the organization, and the practices coordinate to result in learning (Greeno, 2005). The influence of any one component must be considered in relation to the others in situ to fully understand its function. This chapter, then, details design conjectures made about the coordinated function of the tools, tasks, and talk of a video club for secondary science teachers to promote noticing of students' evidence-based reasoning and how those conjectures were tested. Specifically, the analysis will elucidate how the design components functioned in relation to each other to promote teacher learning.

Study Design & Methods

Video Club Context

The professional development program described here involved a video club designed to promote noticing of students' evidence-based reasoning in science to stimulate experimentation with more ambitious instructional practices that would make students' thinking more visible. The participants were five high school science teachers from an urban school district in the southwestern United States. The group included one biology teacher, one chemistry teacher, one physics teacher, one earth science science teacher and one teacher with a split physics/earth science assignment. The participants each had over ten years of teaching experience and were accustomed to working in subject-alike collaborative groups to design and analyze common assessments. As part of the video club, the teachers met approximately once monthly for sixty to ninety minutes after school over the course of one semester.

Drawing on Sandoval's conjecture mapping model (2014), I theorized that using particular types of video clips supported by specific activities and facilitation to frame teachers' noticing of student thinking in the clips would encourage teachers to engage in critical discourse for analyzing students' thinking and the instructional triangle (Borko, et al., 2011; van Es & Sherin, 2006). "Critical" here refers to the level of collaborative critique among colleagues rather than critique of current social culture and structures (Lord, 1994). Sherin and colleagues (2009) found that video clips featuring high windows into students' thinking and high depth of student thinking were more likely to sustain rich discussion about the mathematical content of students' ideas. However, including a promising video clip does not ensure that productive discussion will result. Facilitation that frames the viewer around the professional development goals, encourages collaboration, sustains focus on the evidence in the artifact, and promotes an inquiry stance toward analyzing the video are necessary components for learning from video (van Es, Tunney, Goldsmith, & Seago, 2014). In addition to utilizing these facilitation moves, I engaged participants in two activities to productively frame the participants' viewing of video to focus on students and their learning.

The first type of activity was to have participants complete the task students worked on in the video. I refer to this as the "ideal response" but the intent was not to develop a "correct" answer to evaluate students' response against. The "ideal response" task was designed to help participants clarify the goals of the activity and gain an appreciation of the different ways students might approach the task (Borko et al. 2011; Levin, Hammer, & Coffey, 2009). Additionally, because the participants taught a variety of courses (biology, chemistry, physics, earth science, and environmental science) working through the "ideal response" afforded an opportunity to acquaint participants with content that they might be less familiar with.

The other activity that I hypothesized would clarify goals and focus participants on student reasoning in the clips was to develop a rubric for evidence-based explanations. The rubric was not intended to be something to give to students or to formally assess student work but rather to serve as a way to make explicit how participants conceptualized evidence-based reasoning and make visible what they valued with respect to the development of students' evidence-based reasoning. Because the rubric was revisited several times over the five meetings it would also capture any changes in participants' conceptions and values over time. Additionally, like the "ideal response" activity, it would clarify participants' goals for developing their students' reasoning and help them discern if the tasks they designed for students provided sufficient opportunities for their students to practice and demonstrate reasoning.

Finally, the design included starting with using published, high-quality artifacts to apprentice participants into the type of evidence-based, focused analysis of students' thinking for the first three meetings before transitioning to examining videos of their own classrooms in the last two meetings. The published videos I selected featured students developing causal explanations of their observations of a scientific phenomenon (how a tanker truck that was vacuum sealed after being steam cleaned collapsed, how metabolizing yeast produced gas, how different sized tuning forks and different instruments produced sound waves, and how sound would be produced by different instruments and experienced by the audience at a concert). These videos were drawn from the AmbitiousScienceTeaching.org website. These videos were chosen because they featured high windows into students' causal reasoning about a substantive phenomenon rooted in everyday experience. Because the teacher was rarely present in the video clips I selected, I hypothesized that this would encourage participants to focus on students' ideas. I chose one counterexample that showed students engaging in a more "typical" US classroom lab experience from the TIMSS video set (sunspots and pulleys). Preparing teachers to work with the video of other's classrooms that resemble one's own has been found to be important for promoting self-reflection (Kleinknecht & Schneider, 2013). Teachers who have some experience working with video are more likely to experience engagement with the video and to notice more components of teaching and learning than those who lack experience (Seidel et al., 2011). Starting with videos of classrooms that resembled their own but that they did not have a personal relationship with before transitioning to analyzing artifacts from their own classrooms was hypothesized to not only allow participants to familiarize themselves with the norms for rigorous, evidence-based analysis of student thinking in a lower-stakes environment, but still afford the close examination of their own practice.

Data and Analysis

Data collected included recordings of the five video club meetings and the classroom artifacts (published video clips as well as video and student work collected from the participant's classrooms). The meetings were divided into activity phases (introduction of the lesson, discussion of the "ideal response," analyzing the artifact, discussion of the rubric, and housekeeping) and transcribed. The primary interest of the research question in this study involved how the components of the design coordinated to impact the quality of discourse around the artifacts of teaching. The artifact analysis phases of the meetings were therefore divided by discussion around each artifact (e.g. clip 1, clip 2, student work 1, student work 2) and further divided by idea unit. An idea unit was defined by a set of turns at talk focused on a broad topic (student thinking about the disciplinary core idea) or object (the drawn explanatory model featured in the student work). Five artifact 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 13 artifacts for a total of 54 idea units.

To determine the quality of critical discourse during participants' discussion of students' thinking I categorized the productivity of each idea unit as either high, medium, or low quality based on three dimensions: *What* was being discussed, *how* participants interacted with ideas, and how participants interacted with *each other*. To characterize *what* the teachers noticed, I developed a preliminary set of topic codes informed by the literature on noticing and artifact analysis (Levin et al., 2009; Star & Strickland, 2008; Sherin & van Es, 2009). I applied these preliminary codes to each turn of talk for a portion of the artifact analysis segments of the transcripts. I noted what topics were not captured by the preliminary codes and revised the final topic code set to include instruction, classroom management, student behavior, student thinking, classroom climate, assessment, disciplinary core ideas, or motivation. The modified framework was then used to code each turn of talk for all of the artifact analysis segments. If an utterance involved two topics, for example, assessment of a disciplinary core idea, it was double-coded. Using these turn of talk codes, I determined the main focus of each idea unit for each artifact.

To capture *how* participants engaged with the artifact, I used Sherin and van Es' noticing framework (2009) to code each idea unit for the *stance* they most frequently applied to analyzing the artifacts (descriptive, interpretive, or evaluative) and what they most commonly used as *evidence* to support their statements (anecdotes, artifacts, scientific principles, or a mixture of these). To capture how participants interacted with *each other*, the idea units were coded as increasing levels of participation (*low, medium low, medium high,* or *high*), depending on how many participants were involved in the discussion, whether each participant's contribution built upon earlier comments or consisted of disconnected, discrete conversations, and whether participants critiqued each other's "weak practices or flimsy reasoning" (Lord, 1994, p. 192). Five idea units across two meetings were coded by a research team familiar with the noticing literature to establish reliability of coding.

I then sought to understand how the design elements of the professional development (artifacts, facilitation, and framing tasks) may have coordinated to influence the productivity of the discussion. To determine the influence of the quality of the artifacts on participants' discussion of students' thinking, I first coded each artifact (video or student work sample) for high, medium, or low windows into and depth of student thinking using an adapted form of the Sherin et al. (2009) framework. A colleague familiar with science instruction and artifact analysis double-coded five of the thirteen artifacts to establish reliability of coding. To determine the influence of facilitation moves on participants' discussion I coded the transcripts of the artifact analysis sections of each meeting using the van Es et al. facilitation framework (2014). I coded each of my turns of talk according to the facilitation function it served. In instances where more than one move was employed, these turns of talk were double-coded (see Table 1). A portion of the idea units were coded together with a colleague familiar with the facilitation framework to establish reliability of coding. Frequencies of each move were then tabulated by idea unit. To determine the influence of the framing activities on participants' discussion of students' thinking I noted references to either the evidence-based reasoning rubric or the "ideal response" during the artifact analysis segments of the meetings. Frequencies of references were then tabulated by idea unit.

Table 1

Analytic Framework for Facilitation Moves Employed During Artifact Analysis

Facilitation move	Definition	Example
Orienting group to the analysis of the artifact	*Launching* examination of the clip and *situating* the artifact by providing information about the lesson goals and context.	OK, so let's look at Renaldo. Does this rubric capture some of what's happening in this conversation? She does have them briefly report out on their model. And they stay up in the room um, because they pull them back down and work on them a little some more through the unit.
Promoting an inquiry stance	*Highlighting* evidence from the artifact; *posing a question* about student thinking in the artifact; *making an inference* about a student idea; *pressing* participants to explain their thinking; *clarifying* and *revoicing* their position; *offering an alternative* point of view or information to promote discussion or *challenge* assumptions.	So, they write, "the length changes the pendulum and how fast the period moves. It increases and then begins to become more consistent." So, I'm wondering if he's, like, if he's thinking about speed as in the compression waves come faster, meaning like more frequent versus the speed at which the wave is traveling.

		(And there are no arrows pushing out on any of the diagrams right now), so there's no acknowledgement yet that there is actually pressure still inside it's just changed. What do you see in what he wrote? You're talking about the dent and there's an arrow right by that dent? So, you want him to say something about the distance between the lines? Yeah, but, you know, if we wanted them to use a complete sentence they could say, they could add two these and this becomes a complete sentence and it doesn't really fundamentally change anything about this answer, like about the science anyway.
Maintaining a focus on the artifact	*Redirecting* attention to the artifact; *making connections* between different ideas in the discussion.	Yeah, but well what was the conversation about? What were they talking about?
Supporting group collaboration	Allowing group members time to discuss an issue by "*standing back*"; *inviting* participant's contributions; *validating* and *affirming* contributions; *using humor*; use of *minimal responses* to signal active listening.	What would you want to ask him about, Vince? I struggle with this too. Yeah, I think it's tough. Mmm hmm.
Other	Commentary on issues other than the shared artifact or about the instruction isolated from the instructional triangle.	I think a lot of the science vocabulary words, like theory, hypothesis, gravity, um, force are hard because they have

been co-opted by laypeople to mean something very different.

Yeah, this one group that we're not actually going to watch, but it's pretty interesting. It's like they know that this air is moving inside, and they're like, "it's a tornado."

Findings

A summary table of the analyses of discourse productivity, references to framing activities, and facilitation (see Table 2) reveals three trends. First, Meeting 3, which featured high quality artifacts, and the most frequent references to the framing activities and frequent use of moves to promote an inquiry stance had the highest number of productive idea units. Participants by this time understood how to use evidence from the artifacts and the framing activities to interpret students' thinking. The rubric had developed from a list of topics the group had brainstormed in Meetings 1 and 2 to a more operationalized version with indicators of various levels of sophistication for students' use of evidence, clarity and relevance of claims, connections to a big science idea, and appropriate use of scientific vocabulary. All three components of the activity system (participants, artifacts, framing activities, and facilitation) were coordinated to produce productive talk focused on interpreting students' disciplinary thinking.

Table 2

Use of design elements across three video club phases

	Meeting 1		Meeting 2		Meeting 3		Meeting 4		Meeting 5	
Productivity	High	Less	High	Less	High	Less	High	Less	High	Less
Total idea units	2	9	0	9	11	9	2	4	2	7
Idea units focused on the artifact	2	6	0	7	11	7	2	1	2	5
Idea units focused on anecdotes	0	5	0	4	0	2	0	3	0	7
Total turns of talk	72	177	0	365	369	153	92	127	77	154
References to framing activities	13 (5%)	0 (0%)	0 (0%)	10 (3%)	118 (32%)	28 (18%)	29 (13%)	16 (7%)	22 (10%)	32 (14%)
Artifact quality (windows & depth)*	HH HH		MM LL		HM HM HM MH HH HH		MM MM		MM LM LM LM	
Total facilitation moves	45	52	0	63	167	63	32	48	30	51
Orienting moves	13 (13%)	0 (0%)	0 (0%)	9 (14%)	11 (7%)	14 (22%)	6 (8%)	0 (0%)	6 (7%)	2 (2%)
Promoting moves	22 (23%)	13 (13%)	0 (0%)	47 (75%)	65 (39%)	12 (37%)	9 (11%)	11 (14%)	14 (17%)	25 (31%)
Maintaining moves	0 (0%)	1 (1%)	0 (1%)	4 (6%)	1 (1%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	3 (4%)
Supporting moves	10 (10%)	29 (30%)	0 (0%)	30 (88%)	88 (53%)	30 (48%)	17 (21%)	36 (45%)	10 (12%)	21 (26%)

Note. Percent of references to framing activities represents the ratio of turns of talk that reference the framing activities to the total number of turns of talk. Percent of facilitation moves represents the ratio of the specific move to the total number of moves. * H represents high windows into or depth of student thinking, M represents medium windows or depth, and L represents low windows or depth.

An example of how these elements coordinated to result in highly productive talk in Meeting 3 involves a discussion around a clip featuring physics students' written and oral explanations for what sound waves would be generated by two different-sized tuning forks. I *launched* discussion of this clip by referring to the "ideal response" the group generated prior to watching the clip (see Example 1). The group had established that students should depict compression waves emanating from both tines of the fork, with the larger fork producing waves that are more spaced out (lower frequency) and the smaller fork producing waves that are closer together (higher frequency). Assuming both forks were struck with the same intensity, the size (amplitude) of the waves should be equal.

Example 1

Examining Student Understanding of Tuning Forks

1	Facilitator	OK. So, what do we see in this drawing that we wanted?
2	William	The lines? Compression waves?
3	Vince	Yeah the separation between the lines, yeah.
4	Ron	Yeah.
5	Facilitator	Mmm hmm. Do you see a difference in the separation between the low pitch and the high pitch?
6	William	I see I see more lines in the high pitch than I see in the low pitch.
7	Vince	Yeah.
8	William	And to me there-
9	Vince	-On one side, like on the low pitch side, there seems to be more space there by compared to just the left-hand sides. There's the one on the right they are closer together than the one on the left.
10	Facilitator	Mmm hmm.
11	Vince	The drawings on the right, it is kind of hard to tell, I know the one on the right has more lines than the one on the left, but-
12	William	-Low pitch means like low voice, right, like low?
13	Facilitator	Mmm hmm.
14	William	See that right now to me, means the kid has a higher, like wants to say a higher volume for the one on the right versus to the one on the left so pitch versus volume, I mean, I get what you're trying to say with pitch but as the student I think that he might, there might be a, there might be a kinda like, not understanding pitch and volume, right?
15	Facilitator	Yeah, it's unclear right now.
16	William	I mean he clearly writes high pitch and low pitch.

17	Facilitator	Yeah, “it would sound lower and have lower sound waves.”
18	William	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?
19	Ron	According to the [inaudible] they would both be the same sound, same amplitude.
20	William	Yeah, but they, but if they start at the same time, [gestures] they have the same energy, they would have the same volume at the same distance, right? Then that’s a good question I would ask the student. And that would confirm or deny that they understand high pitch if it has those lines or not.

In this sequence, participants describe, interpret, and respond to student ideas about sound using specific evidence from the clip and referencing the “ideal response.” In lines 2-11, the group collaboratively describes details of the work, building on what each other noticed about the differences in the number and spacing of the lines representing compression waves coming from the forks. In line 12 William starts to conjecture what these details might mean about the student’s understanding, suggesting that the student might have been confusing pitch and volume (amplitude) because the student wrote that one of the forks would sound “low.” It was unclear if the student understood that low pitch did not always mean low in volume as well. Ron references the “ideal response” in line 19 to make sense of the student’s response. In line 20 William proposes a teaching move that might clarify if the student understood that pitch and volume were separate factors, making a connection between the students’ thinking and instruction. After *launching* the discussion, my facilitation consisted mostly of *standing back* and *affirming* responses to support continued participation and included one move to promote an inquiry stance by *posing a question* about details in the students’ answer in line 5. The high affordance of the artifact, facilitation to support and promote inquiry, and participants’ familiarity with noticing student thinking and using it and the tool produced by the framing activity as evidence coordinated to produce productive discourse in this meeting.

Second, the influence of the framing activities shifted over time. The rubric, because it was constructed by the participants during the video club meetings as they refined their thinking about what they valued in students’ evidence-based explanations through viewing artifacts, had a different affordance for supporting critical discourse in earlier meetings relative to later meetings. Participants made little reference to the rubric in Meetings 1 and 2 because it only consisted of a list of topics. They used the more developed rubric with indicators of various levels of quality to analyze students’ explanations in Meeting 3 because the artifacts made visible the students’ thinking about complex ideas. Later, in Meetings 4 and 5 when participants began to examine artifacts from their own classrooms, they used the rubric to problematize their own instruction.

An example of how participants used the rubric and evidence from the artifact to problematize instruction comes from Meeting 5. Mitch shared a video clip and student work produced by his students as they explored what factors influenced a pendulum’s period. After leading students through a demonstration to show that mass does not affect the period of a pendulum, Mitch charged his students with collecting ten period measurements of varying pendulum lengths of their choice, graphing their results, and orally reporting their findings 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 length of the pendulum.

In our meeting, Mitch took the initiative to raise one artifact for examination by the group, noting 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 observed that the students started with the correct relationship but in their attempt to clarify their answer (one of the elements the group identified as important in their evidence-based reasoning rubric) they mentioned something that was not in their data – string height – and that this addition was not correct because amplitude has no influence on the period. Laurel, Mitch, Ron and I attempted to sort out what the students really meant when they wrote "the higher the string is held," and some alternate possibilities besides amplitude were proposed. This led to Mitch raising a question about the task design:

Example 2

Exploring the Instructional Triangle Around Pendulums

1	Mitch	I wonder about the medium quality. We're supposed to be getting closer to this medium quality for this. And, uh, I dunno. Is there a difference between medium and high quality in this prompt?
2	Facilitator	Does the prompt afford that? I don't know. You know and I think that, that is what is really tricky is a lot of what we get from the students hinges on how the prompt, the problem prompt is crafted. And unless you go through this exercise of like, well what do I really want them to know? Well, do I really want them to know all that? Do I want more than that? Like, really refining in your head what it is, like being very clear about that. And then, so now, how do I need to phrase this? And sometimes it's not even the phrasing of the question, it's like, I'm having, they're engaging in the wrong task.
3	Laurel	Yeah.
4	Mitch	You can see that I changed the prompt, right?
5	Laurel	Yeah.
6	Mitch	So now it makes sense because I wanted it to be more about the line matching, and so I changed the prompt to say which one of these looks like a match to what you are seeing. And so, I could have asked for more detail there, but clearly, this class probably needed just the idea of the relationship of the longer length to longer period. But I wanted to get into this discussion about is it this one or is it this one [pointing to linear and log graphs].

After *highlighting* evidence from the artifact to describe and interpret the student thinking Mitch shifted the discussion to the design of the prompt. He wondered 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 he wanted students to understand when discussing the "ideal response" earlier in the meeting. Mitch *posed* and I *revoiced a question* to connect our analysis to instruction and Mitch mentioned how he changed his instruction in response to what he noticed about students' work in class. Although this particular artifact only has medium windows into and depth of student thinking, it, combined with the affordances of the ideal response and the rubric sustained inquiry into student thinking and how it was potentially influenced by the nature of the task design.

Third, just as the rubric took on a different role in later meetings as it developed, so did the participants themselves. As participants were apprenticed into the type of critical discourse for analyzing students' thinking they took on the role of *highlighting* evidence from the clips and using references to the framing activities in their inquiry, the total number and type of facilitation moves I employed decreased. I used more moves to orient participants to the clips I selected in early meetings and actively modeled the *highlighting* of evidence to promote inquiry in early meetings. The number of these moves decrease over time with a greater proportion of my moves including supporting participants in their inquiry of student thinking in Meeting 3 and of their own students and instruction in Meetings 4 and 5. Although the participants understood how to use evidence from the artifacts and the framing activities in their inquiry, the artifacts featured in these meetings had fewer affordances to sustain conversation due to their lower windows into and depth of student thinking. The quality of the artifacts made it more challenging to use promoting moves such as *highlighting* and *pressing* because there was less evidence of students' thinking to work with. These meetings still yielded more productive idea units than Meeting 1 because the greater affordances in terms of participants' learning and the tools from the framing activities were able to make up for the lower affordances of the artifacts.

A juxtaposition to the type of discourse that resulted from the coordination of the tools, tasks, and talk in Meeting 5 is the lack of coordination of these same components from Meeting 2. I noticed that the participation of Ron, the lone biology teacher of group, might have been negatively impacted by his unfamiliarity with the physical science concepts featured in the Meeting 1 artifacts. I could not find a life science artifact with high windows into and depth of student thinking but did find one with medium levels of these features. The clip showed students trying to make sense of their observations of flasks with yeast, sugar, and water in terms of metabolism and reproduction. As we discussed our "ideal response," it became clear that the teacher in this clip was approaching the relationship between cellular respiration, reproduction, and metabolism in a way Ron was not familiar with and one he questioned repeatedly during the analysis of the clip. After we watched part of a video clip, I *launched* a discussion by *highlighting* evidence from the clip to an idea about evidence that arose when we worked on the evidence-based rubric earlier in the meeting.

Example 3

Discussing a lesson on yeast metabolism

Facilitator	So that's actually another piece of evidence, where you mentioned like the kids need to pay attention to the balloon, right? The kids, so this kid, I don't remember if she noticed on her own like woah what's happening at the bottom of the flask, like stuff is disappearing.
Ron	You'd have to put a lot of sugar in though… we added, I don't remember how much we added.
Mitch	I mean it's not saturated. It's not even a significant quantity by volume. It's, so it would be interesting to work out why that H_2O is going down. But anyway, they notice the H_2O goes down. So, the kids seem to know the knowledge-based information. They know that the gas is CO_2, right?
Facilitator	Mmm hmm…. Let's listen to more about what they say.

Ron	I just don't understand how, sorry to interrupt you, I don't understand how that teacher can tolerate that kid yelling, "what's the temperature? What's the temperature?"
Mitch	[laughing]
Ron	Well, you're not paying attention to what the conversation is... The kid is talking right in front of the two people that are talking across from each other! She's almost having a conversation with the girl and not with the group!

Rather than interpreting what the student said about why their balloon was inflating and what that meant about the students' understanding of respiration, Ron attempts to compare this lab with a similar one he ran with students. Mitch acknowledges this but then turns his attention back to students' understanding about the gas captured in the balloon. I attempt to *redirect* attention back to the clip but Ron interrupts with a critique about how the teacher is managing the discussion among the lab group. Only Ron and Mitch were able to attend this particular meeting and they frequently engaged in critiques about the instruction despite my efforts to *redirect* attention back to the evidence of student thinking I *highlighted* in the clips. The "ideal response" discussion around this artifact, the nascent state of the evidence-based reasoning rubric, and the absence of three group members contributed to the failure of the activity system in this meeting to support productive discourse around artifacts of similar quality in Meetings 4 and 5.

Discussion & Conclusion

Analyzing the components of this video club affirms that participants, artifacts, facilitation, framing activities and the tools that result from them coordinate to support a variety of levels of discourse. Over the course of the video club participants learned to notice students' thinking and leverage it as evidence to reason about teaching and learning. Participants increasingly took on the roles of promoting inquiry and used tools they generated by the framing activities to sustain their conversations. Discourse was at its most productive when artifacts, tools, facilitation and participants operated at their highest affordances. This was seen in Meeting 3 when participants who were accustomed to and supported in noticing students' ideas worked with artifacts featuring high windows into students' thinking about meaningful science ideas. Facilitation and activity in early meetings apprenticed the participants into the work of exploring students' thinking and making connections between the students' ideas and the instructional moves that made that thinking visible.

This design combined the use of the videos of others' classrooms with videos from participants' own classrooms. Following the recommendation of Kleinknecht & Schneider (2013), participants in this study used videos of others' classrooms with students that resembled their own to hone their skills of analysis before applying these skills to their own videos. Indeed, the proportion of highly productive idea units peaked in Meeting 3 after two previous meetings of work with quality artifacts supported with facilitation and activities to focus attention on student thinking. Seidel and colleagues (2011) found that teachers who viewed their own videos noticed more aspects of teaching and learning *if they had previous experience working with video*. Teachers in their study reported working with their own videos to be more relevant and engaging. It could be the case that the quality of the clips used in this video club combined with the rubric and "ideal response" development provided enough relevance to engage the participants in this study, even when working with the video of others. The quality of the video captured from participants' own classrooms were lower in both windows and depth compared to the videos used in early meetings, and the productivity of discussion decreased in Meeting 2 even when the affordances of the videos dipped from high windows and depth to medium. This indicates that had we started with participant's own videos, their clips may not have provided sufficient evidence of student thinking for the participants to develop their noticing and inquiry skills. This study design did not attempt to juxtapose the two models (own first versus other first) but does provide some evidence that the quality of the video should be privileged over participants' desire to work with their own videos, particularly when relevance can be achieved with other supports. The field would benefit from further exploration of this design question.

Analysis of this activity system also affirmed previous findings that just providing high quality artifacts (Sherin et al, 2009; Zhang et al., 2011a) or facilitation (Coles, 2013; van Es et al., 2014; Zhang et al., 2011b) does not guarantee productive discourse. The artifacts that featured high windows into and depth of student thinking in combination with facilitation moves to orient, promote, maintain, and support inquiry did not coordinate to produce sustained productive discourse in Meeting 1. Despite the use of high-quality artifacts and facilitation to support that work, participants were still in the process of being apprenticed into the noticing of students' thinking and leveraging what they noticed as evidence to support their interpretations about teaching and learning. The affordances of artifacts and facilitation alone were not sufficient to sustain highly productive discourse about student thinking. Relatedly in Meeting 2, despite aggressive facilitation to support and promote inquiry in students' thinking, this meeting yielded no highly productive idea units in the absence of several group members, quality artifacts, and sufficiently developed tools.

The example of choosing artifacts with lower affordances in Meetings 2, 4, and 5 highlights tensions as a designer and facilitator of video-based professional development. My goal to support participation by choosing an artifact to better position Ron as a knowledgeable contributor and to honor the participants' desire to explore artifacts from their own classrooms was in conflict with my goal to feature artifacts of high quality to promote sustained discussion and model ambitious, student-centered instruction. Another tension involved supportive facilitation to encourage participation and facilitation to promote critical discourse. The most frequently used move across all phases of the video club was support, and this move was particularly frequent in less productive idea units. Zhang et al., (2011b) found that quick, frequent, and affirmative revoicing may have limited hypothesizing among teacher participants. That could also have been the case here, particularly in Meeting 2 when the affordances of other elements of the activity system were low. Such "decision points" (Coles, 2013) mark tensions within the design. An activity system frame of analysis will help further clarify tensions between elements of learning systems and perhaps shed light on potential strategies for how to navigate them. Assessing the affordances and limitations of the various elements of the activity system at any point in the learning trajectory of the group could inform decisions that lead to more productive outcomes. The feasibility of making these types of affordance/limitations calculations on the fly is an interesting route for further explorations.

Because the productivity of a group results not just from the inclusion of a few important components, but from the coordination of these components, further investigation into how each component takes on different amounts of responsibility across the developmental arc of video-based professional development is a worthy avenue of further research. Such examinations of how components in activity systems change over time will yield valuable insights for the design of video-based professional development as well as how best to facilitate teacher learning in dynamic learning systems.

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