Journal of Teacher Education
2022, Vol. 73(4) 352–365

DOI: 10.1177/00224871211056577
journals.sagepub.com/home/jte
SAGE

Designing for Framing in Online Teacher Education: Supporting Teachers' Attending to Student Thinking in Video Discussions of Classroom Engineering

Jessica Watkins[1] and Merredith Portsmore[2]

Abstract

Participating in discussions of classroom video can support teachers to attend to student thinking. Central to the success of these discussions is how teachers interpret the activity they are engaged in—how teachers *frame* what they are doing. In asynchronous online environments, negotiating framing poses challenges, given that interactions are not in real time and often require written text. We present findings from an online course designed to support teachers to frame video discussions as making sense of student thinking. In an engineering pedagogy course designed to emphasize responsiveness to students' thinking, we documented shifts in teachers' framing, with teachers more frequently making sense of, rather than evaluating, student thinking later in the course. These findings show that it is possible to design an asynchronous online course to productively engage teachers in video discussions and inform theory development in online teacher education.

Keywords

responsive teaching, practice-based teacher education, online teacher learning, design-based research

Introduction

A central goal in teacher education is to support teachers' attending to student thinking, in which teachers notice, interpret, and build on students' ideas, experiences, and perspectives (Kazemi & Franke, 2004; Robertson et al., 2015; Sherin & van Es, 2009; Windschitl et al., 2012). Studies show that teachers' attending to student thinking is positively related to students' learning (Pierson, 2008; Radoff et al., 2018) and can support higher levels of disciplinary rigor and sensemaking in classroom discussions (Coffey et al., 2011; Thompson et al., 2016). Moreover, what teachers attend to classroom activity can send messages to students about what and who are valued (Gresalfi et al., 2009; Russ, 2018), motivating the need to support teachers to value more diverse entry points to disciplinary activities (Bang et al., 2017; Haverly et al., 2020; Rosebery et al., 2016). From this perspective, in attending to student thinking, teachers need to seek to *make sense of*, rather than simply *evaluate*, students' reasoning.

To support teachers' making sense of student thinking, teacher educators have used classroom video as an artifact for reflection and learning (Borko et al., 2008; Gaudin & Chaliès, 2015; Hammer & van Zee, 2006; Sherin & van Es, 2009; Star & Strickland, 2008; Tekkumru-Kisa & Stein, 2015). Programs designed to help teachers unpack students' thinking through video discussions have shown progress in what teachers notice and their stances toward student thinking (Rosebery et al., 2016; Sherin & Han, 2004; Tekkumru-Kisa & Stein, 2015; van Es & Sherin, 2008), how they participate in video discussions (van Es, 2009), and their classroom practice (Sun & van Es, 2015; van Es et al., 2017; van Es & Sherin, 2010). However, most programs have taken place in face-to-face settings. Research on video use in online programs has focused on different aspects of teachers' participation, such as whether teachers ground their comments in specific events (Nemirovsky & Galvis, 2004), whether they make connections between theory and practice (Koc et al., 2009; Llinares & Valls, 2009), and how annotation tools support coaching (Choppin et al., 2020). Given the rise of online learning environments in teacher education, we were motivated to study whether and how teachers in an

[1]Vanderbilt University, Nashville, TN, USA
[2]Tufts University, Medford, MA, USA

Corresponding Author:
Jessica Watkins, Department of Teaching and Learning, Vanderbilt University, 230 Appleton Place PMB230, Nashville, TN 37203, USA.
Email: jessica.watkins@vanderbilt.edu

asynchronous, web-based course engage in video discussions to make sense of student thinking.

Research on online professional development (PD) provides evidence that these environments can be as effective as face-to-face programs (Dede et al., 2016; Fishman et al., 2013), but there is a need to better conceptualize the relationships between web-based technologies, facilitator and participant interactions, and teachers' learning (Dede et al., 2009; Moon et al., 2013). To accompany this theory development, there is also a need for empirical studies that go beyond showing what is possible to provide detailed articulations of the guiding principles and descriptions of features that foster teacher learning (Moon et al., 2013).

In this article, we contribute to both the theory-building and empirical work called for in online teacher education. We take the perspective that a key challenge to online teacher education, including online video discussions, centers on helping teachers figure out what kind of learning activity they are engaged in and how it relates to their classroom teaching. Given that many teacher education programs are seeking to disrupt or reshape long-held norms of classroom teaching, teachers are often asked to engage in professional learning activities that may be unfamiliar or whose purpose may not be clear to them. In face-to-face discussions of classroom video, for instance, there is evidence that teachers often do not immediately interpret the objectives of this activity as opportunities to make sense of the meaning of students' words and actions (Sherin & Han, 2004; Tekkumru-Kisa & Stein, 2015; van Es & Sherin, 2008). Therefore, we argue that supporting teachers to productively engage in online video discussions centrally involves negotiating how they interpret, or *frame*, what is taking place and what is expected of them.

Drawing on work from anthropology and sociolinguistics (Bateson, 1972; Goffman, 1974; Tannen, 1993), we centrally considered teachers' framing in the design and examination of video-based discussions in an online graduate course in engineering education for in-service K-12 teachers. Every week, teachers watched and commented on videos of students' engineering using a web-based video annotation tool. This technology linked teachers' comments to specific times in the video, allowing others to see and reply to comments at particular moments. We developed conjectures for how to design and implement the video discussions to support teachers' framing these discussions as opportunities to make sense of student thinking. Examining teachers' written comments, we asked:

1. How did teachers frame online video discussions of students' engineering in an online course designed to focus on student thinking?
2. What are shifts in how teachers framed the discussions from the start to end of the course?

Next, we elaborate on our theoretical perspectives that relate framing to teachers' attending to student thinking. We consider how these perspectives inform the design and implementation of video discussions and then describe our conjectures for developing online video discussions. We then present our analysis of teachers' online written comments on videos of students engaged in engineering design, looking into the ways teachers framed these discussions and whether there were differences in their framing from the start to the end of the course.

Theoretical Perspectives

This study builds on extensive work on teacher noticing, which has characterized what teachers notice in video clubs and discussions. In this section, we describe how these aspects of teacher noticing are related to how teachers frame the activity in which they are engaged, then discuss how this perspective can inform the design of online video discussions.

Framing and Teacher Noticing

In any activity, participants make interpretations about what is taking place; these interpretations, or framings, of an activity shape what they attend to and how they respond (Bateson, 1972; Goffman, 1974; Tannen, 1993). Scholarship on teacher noticing has highlighted the relationship between what teachers attend to in classrooms or videos and how they are framing their interactions (Luna & Sherin, 2017; Russ & Luna, 2013; Sherin & Russ, 2014). For instance, Sherin and Russ (2014) documented teachers' frames in video-based interviews, arguing that these frames offer a way to characterize the networks of ideas that teachers apply in noticing and reasoning about classroom interactions. Russ and Luna (2013) looked into local patterns of teacher noticing to infer how teachers are framing classroom activities and use framing as a way to explain variation in teachers' noticing. Similarly, Erickson (2011) talked about the role that narrative frames can play—teachers' noticing is embedded within the stories they tell about students and what is taking place. Common across this work is the perspective that, in video discussions and in classroom teaching, teachers are interpreting the nature of their activities, figuring out what it is they and others are doing in these contexts. These interpretations then shape what teachers attend to in videos or classroom activity.

Framing is dynamic and contextual: How teachers interpret what is taking place can shift from moment-to-moment, in response to unfolding activity. Therefore, just as framing shapes what teachers attend to, what teachers notice can shape their interpretations of activities (Russ & Luna, 2013). For instance, Lau (2010) documented moment-to-moment variability in how a teacher responded to student thinking in her classroom. When a student made a puzzling comment, the teacher sought to make sense of his thinking by asking questions about his meaning. When this same student used a vocabulary word, she shifted back to covering her curricular objectives, only writing down the vocabulary word rather than the student's idea.

Recognizing the dynamics of framing and noticing informs our conceptualizations of teacher learning in this domain. Learning to attend to student thinking is, at least in part, a matter of learning to frame video discussions and classroom activities as opportunities to make sense of what students are saying and doing. This perspective builds from the work of Levin et al. (2009), who showed that novice teachers could attend to students' scientific ideas, even at the start of a teacher education program. Therefore, instead of conceptualizing their learning as developing abilities to notice, they consider how teachers learn to frame their classroom activities differently, in ways that focus on students' reasoning. Similarly, Kang and Anderson (2015) documented how novice teachers who advanced in their noticing of student thinking became flexible in navigating different framings of classroom activity, learning to shift to attending to student thinking after focusing on classroom management.

Given that teachers are embedded in cultural and political contexts that pose barriers for teacher noticing (Louie, 2018), alongside work to transform these systems, a central goal for teachers' learning is to develop stability in framing their teaching as attending to student thinking. One aspect of developing stability is for teachers to more often and more readily frame video discussions and classroom events as opportunities to make sense of what students are thinking. To think about how teachers might develop this stability, we unpack how framing is both informed by teachers' prior experiences and negotiated in interactions. We then consider how to design online programs to negotiate framing with participants and support them to more stably take up video discussions as making sense of student thinking.

Negotiating Framing in Video Discussions

How teachers frame a classroom event or professional learning activity is informed by their prior knowledge and experiences (Goffman, 1974; Tannen, 1993). Many science teachers, for instance, may have only experienced science class as "receiving information from the instructor," posing challenges for seeing their classrooms in new ways. Similarly, for teachers' professional learning activities, like video clubs, teachers draw on their prior experiences to make sense of what is taking place. Given that many teachers start off in video discussions evaluating students' ideas for correctness (Sherin & van Es, 2009), it is likely that teachers are interpreting these activities as assessment exercises, shaped by the emphasis in U.S. schools on testing and grades.

However, framing is also socially negotiated: using multimodal forms of communication, participants signal to each other what kind of activity is going on, negotiating the frame of their interaction (Tannen & Wallat, 1993). In classrooms and professional learning contexts, how teachers frame their activities is shaped by and shapes their interactions with their environment including, as discussed earlier, what they notice in student thinking.

Recognizing that framing is shaped by one's prior experiences and negotiated among participants can inform the design and implementation of professional learning activities with teachers. In video clubs, there is a growing research on the facilitation of video discussions. Building on work on the facilitation of PD more broadly, researchers have characterized how instructors foster rich discussions around video, highlighting moves like eliciting teachers' thinking, validating participant contributions, redirecting the discussion back to video, and connecting to key disciplinary and pedagogical ideas (Borko et al., 2014; Tekkumru-Kisa & Stein, 2017; van Es et al., 2014). We propose that these moves are, at least in part, serving to negotiate the kind of activity that the teachers are engaged in, helping teachers to frame video discussions in productive ways within the PD program. For instance, if a teacher starts a discussion by evaluating the instructional moves and proposing alternatives, a facilitator can redirect them by asking what they saw in students' work that motivated their instructional suggestions (van Es et al., 2014). This move would serve as a bid to shift the framing of the discussion to unpacking student thinking.

In these studies, video discussion facilitation all took place in face-to-face settings, where instructors and teachers can, in real time, work together to develop shared interpretations of what they are doing together as they comment on classroom video. In online, asynchronous settings, attending to teachers' framing will necessarily be constrained. For one, the asynchronous timing means that facilitators will not be able to immediately respond to teachers' comments, limiting the back-and-forth exchanges that help participants develop a shared frame (Tannen & Wallat, 1993). Face-to-face settings also allow for multiple channels of communication; facilitators and teachers can use facial expressions, tone of voice, gestures, and body positioning to signal how they are interpreting their activity and to negotiate framing (Bateson, 1972; Scherr & Hammer, 2009; Tannen & Wallat, 1993). Although emerging technologies allow for different media to be uploaded, online platforms are still more limited in how they structure interactions, motivating creativity in how to structure and facilitate discussions (Collison et al., 2000; Rovai, 2007).

With these constraints in mind, we designed a course that incorporated online video discussions to support teachers' attending to student thinking. By foregrounding teachers' framing, we developed conjectures to help teachers interpret the video discussions as opportunities to make sense of student thinking.

Designing for Teachers' Framing of Online Video Discussions

We developed and implemented online video discussions within Tufts Teacher Engineering Education Program, www.

teep.tufts.edu, an asynchronous, online graduate certificate program in engineering education for in-service K-12 educators. Over 18 months, educators take four courses; two courses focus on engineering content, including learning engineering and engaging in authentic design tasks, and two on issues of pedagogy.

The second course of the program, Engineering Pedagogy, is when teachers first participate in online discussions of classroom videos of students' engagement in engineering. This course was taught by two co-instructors and three to four part-time teaching assistants TA. The course objectives are for teachers to unpack what it means to learn engineering and to develop how they attend to student thinking in engineering tasks. The course includes three main components: teachers (a) read journal articles in engineering education, (b) conduct and analyze interviews with learners about how a device (e.g., pull-back car) works, and (c) watch and discuss videos of students' engineering work. For the final project, teachers either adapted an existing lesson plan or collected and analyzed artifacts of students' engineering in their classroom.

We proposed and mapped two conjectures (Sandoval, 2004) for helping teachers to frame the video discussions as opportunities to make sense of student thinking. Our first conjecture is that teachers need to experience video discussions as coherent with the broader course; video discussions need to address course goals, align with other course activities, and connect to their classroom teaching. The second is that by focusing on and interpreting teachers' thinking, instructors can help teachers frame the video discussions as making sense of student thinking. This conjecture considers teachers as learners, and therefore, the role of instruction is to elicit and build on productive beginnings in *teachers'* thinking, in this case to help them refine how they frame the activity of discussing videos of students' engineering. We unpack each conjecture below.

Coherence

Our first conjecture was that by prioritizing *coherence* across teachers' course activities, we would support teachers in framing the video discussions as opportunities to make sense of student thinking. We anticipated that a consistent course-wide emphasis on the importance of attending to student thinking in engineering and explicit connections between the discussions and other course activities would help teachers frame the video discussions as making sense of what students were saying and doing. This conjecture is also informed by prior literature emphasizing the importance of coherence in teacher PD (Garet et al., 2001; Penuel et al., 2007).

To embody this conjecture, the video discussions were *connected to other course activities focused on making sense of student thinking*. The overarching goal for the course is for teachers to learn to make sense of students' ideas and approaches in engineering. To this end, we asked teachers to read data-rich articles focused on students' engineering each week. We selected readings that both addressed an important aspect of engineering thinking and had examples of student thinking (i.e., transcripts or other artifacts). Instructors then selected videos of students' engineering that would give teachers opportunities to see the aspects of engineering thinking highlighted in that week's reading, similar to work that provides frameworks to attune teachers to aspects of student thinking (Walkoe, 2015). For instance, when teachers read about the integration of science and engineering (Valtorta & Berland, 2015), they watched a video that showed fifth graders drawing on their understanding of heat transfer to design a structure that could stay cool under the sun (Wendell et al., 2016). Instructors also designed the other course activities to center on attending to student thinking: Teachers conducted two interviews with learners about how an everyday device worked (Russ & Sherin, 2013).

We also provided materials that *explicitly linked video discussions with the course goals* and detailed expectations for the video discussions, namely, that teachers should start by attending to what students are saying and doing. These materials also linked the video discussions with their classroom teaching, so they might (a) anticipate what students' thinking in engineering and (b) become practiced at making sense of students' thinking.

Responsiveness

Our second conjecture focused on the need to be responsive to teachers' thinking, by building on potentially generative beginnings in how they attend to student thinking (Levin et al., 2009). This conjecture is informed by theoretical perspectives that teachers' thinking, just as learners' thinking, is contextual and dynamic; our aim as teacher educators is to elicit, interpret, and respond to teachers' emerging ideas about learning and teaching engineering. In this way, the course was designed to embody the very pedagogical principles we hoped teachers would develop. From our theoretical perspective, taking a responsive approach would help instructors better negotiate the nature of this activity, although we had to think creatively about how to be responsive in an online asynchronous environment.

To enact this conjecture, we first tried to *provide orienting written comments* on the video discussions that prompted for and responded to teachers' interpretations. Analyzing these comments, we found that they often modeled genuine engagement with students' thinking as a way to negotiate framing. In one comment posted on an early video of two students collaborating on a design for baby swans, a (TA) remarked, "[Student] asks 'How would they steer it?' His use of 'they' makes me wonder if maybe the raft isn't for Louie. . .could it be for other baby swans?" This comment points to a line in the transcript, making an interpretation of who the student Alex might be designing a raft for. Another way instructional staff engaged in the video discussions was to ask questions of teachers, prompting for evidence for their interpretations or to elaborate on their ideas. For instance, instructors asked what observations led teachers to make a particular claim, which could redirect teachers to making sense of students' ideas.[1] However, to our surprise given prior work on high-quality facilitation in video clubs (van Es et al., 2014), we observed that this design feature was limited in value. Facilitator comments were asynchronous, limited in number (there were 0–10 facilitator comments per video, average 3.5 comments), and restricted to written text. They rarely prompted extended exchanges among participants. We also noted no meaningful differences between groups with many comments and those with little to no facilitator comments.

In response to the limited opportunities for facilitation on the video annotation platform, we iterated our design to *develop a responsive video podcast*. Each week, the two instructors read through teachers' comments on the videos. They then synthesized themes across comments and highlighted key interpretations of student thinking made by teachers. Although the instructors had sketched out some general ideas prior to each week based on the readings and videos, much of the substance of the podcast emerged from analysis of teachers' comments. In this way, instruction was tailored to teachers' thinking, particularly to negotiate teachers' framing of the video discussions.

The responsive podcast also helped us address a key challenge in teaching online, asynchronously: the loss of multiple channels of communication in face-to-face interactions. Tone of voice, gestures, and facial expressions are all important for participants in interpreting and negotiating framing (Scherr & Hammer, 2009; Tannen & Wallat, 1993). The podcast model allowed instructors to use video to draw on multimodal forms of communication when responding to teachers' video discussions that week. These videos allowed instructors to model their genuine engagement both with student thinking in the video and with teachers' online comments.

The podcasts were recorded after teachers had discussed that week's video. The podcasts responded to and negotiated how teachers were framing the discussions; teachers did not respond to the podcast, instead, the next week's video discussion started. To illustrate how our video podcasts were responsive to teachers' thinking, we present the following excerpt. In this example, the video discussions had been on teachers' interviews with students about how a retractable pen worked. One teacher's interview had been especially challenging to understand: The student had talked about "wires" and "lines" inside the pen, and instructors, along with teachers, were unsure of his meaning. In reviewing teachers' comments, instructors noticed that one teacher, Matthew, suggested a promising possibility for what the student may have meant. Instructors thought his interpretation was powerful for showing how to make sense of students' thinking, especially when their meaning is not immediately clear. In addition, thus far in the course, Matthew had rarely framed the video discussions as making sense of students' thinking, so instructors wanted to acknowledge his progress. Instructors used the video podcast to highlight his interpretation and share enthusiasm for making sense of students' meaning:

> Instructor 1: [The teacher] asks: What would you think you would see inside if you opened [the pen] up, and [the student] talks about wires. So some people were like, was he talking about electrical wires? Is he used to seeing other things opened up and seeing wires? But then, Matthew . . . says maybe he's talking about a spring.
> Instructor 2: Oooh!
> [laughter]
> Instructor 2: Oh-ho! Those are the lines.
> Instructor 1: Could it be? So that is my new, like- I went back and was like- "It goes around on the outside-" that's the line. So he's talking about the shape maybe when he's talking about the lines.
> Instructor 2: Fantastic.
> Instructor 1: I felt so much better, after Matthew's comment. [laughter] Almost a sense of relaxation. Like I could relax because I felt like I understand [student] better.

We see these few moments as embodying the principle of responsiveness: Instructors drew on productive beginnings in teachers' interpretations to support framing the video discussions as opportunities to make sense of student thinking. The instructors centered their remarks on how teachers had interpreted a student's idea about "wires" inside the pen. Although many teachers had suggested that the student had been referring to electrical wires, one teacher, Matthew, came up with a different idea that "wires" meant a spring. The instructors unpack and expand on this teacher's interpretation, using gestures to represent this idea and applying it to other portions of the video ("I went back and. . . [student is] talking about the shape maybe when he's talking about the line."). In doing so, the instructors position themselves as learning from what the teachers see in student thinking. They situate themselves within a classroom community that is working together—instructors and teachers—to figure out student thinking. The instructors also call attention to the contributions of a teacher who had been struggling with making sense of student thinking; these moves could serve to both encourage this individual to continue in his efforts and raise his status within the cohort. Finally, the instructors' emotional displays played a prominent role in their response. At the start, Instructor 1 expressed her own puzzlement about the student's idea, modeling key affective aspects of making sense of student thinking. Similarly, both instructors voiced their excitement and relief in response to a teacher's possible resolution of this puzzle. With these displays, the instructors modeled emotional engagement with students' ideas and amplified affective dimensions of framing these discussions as seeking to understand student thinking.

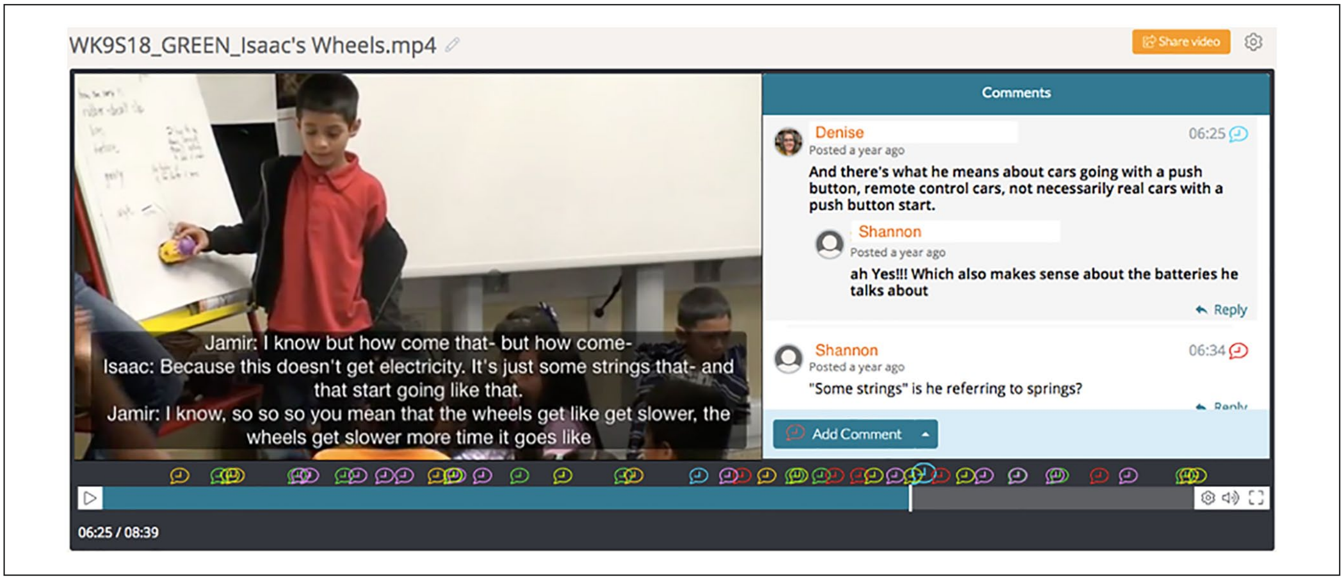

Figure 1. Screenshot of Torsh Talent video platform.

We also explored patterns in how instructors negotiated framing in this medium, conducting a thematic analysis (Braun & Clarke, 2012) of podcast transcripts from one course. A table detailing themes describing how instructors negotiated framing is included in the supplemental materials. Here we point out that instructors primarily negotiated framing by (a) connecting to learning goals and other course activities; (b) supporting teachers' general participation, and (c) responding to the substance of teachers' comments. In the example above, we see elements from this last theme: Instructors *highlighted* key aspects of what and how teachers attended to in the videos and *modeled* engagement in making sense of student thinking. Another way instructors responded was to *reframe* teachers' comments to focus on making sense of student thinking, but this theme only emerged two times. Looking across the course, we not only saw similar themes emerge in each podcast but also noticed instructors did not *model* in later weeks.

With this course design, we analyzed teachers' framing of the online video discussions, namely, whether their comments indicated that they were making sense of student thinking. Next, we provide more context about the course and detail our analytic approach.

Method

Description of Course

We examined video discussions in two different semesters of the Engineering Pedagogy course. In Spring 2017, 24 teachers were taught by both authors; in Spring 2018, 23 teachers were taught by the second author and another colleague. Program participants included K-12 classroom teachers, STEM specialists, media specialists, and out-of-school educators located in the United States and internationally. To foster community, we separated teachers into four groups based on the grade level they taught. In these groups, teachers read and responded to each other's reading reflections and participated in video discussions.

The online video discussions took place on the Torsh Talent video annotation platform. This platform allowed course instructors and teachers to upload and share videos of students' engineering. Teachers could view the video and post time-linked comments and replies to each other's comments; these comments would then appear to the rest of the group as the video played (Figure 1). In Figure 2, we depict the weekly schedule for reading reflections and video discussions. As we detailed above, most weeks teachers discussed videos collected from earlier projects and that were selected to pair with that weeks' reading, which could help attune teachers to particular aspects in videos, such as when students use science and mathematics in their engineering work. These eight videos offered rich and clear depictions of student thinking in engineering design (Sherin et al., 2009). During 4 weeks, teachers discussed videos of the interviews they conducted with a learner. Throughout the week, instructors and TAs checked in periodically to post questions and replies, but these comments were variable in quantity.

Data Collection

We downloaded teachers' comments on two videos from early in the semester and on two videos from later in the course, pairing early and later videos that addressed similar aspects of engineering design. One pair of videos showcased aspects of students' design processes, in which students were brainstorming and planning solutions, building their prototypes, and/or sharing initial design ideas. Another pair

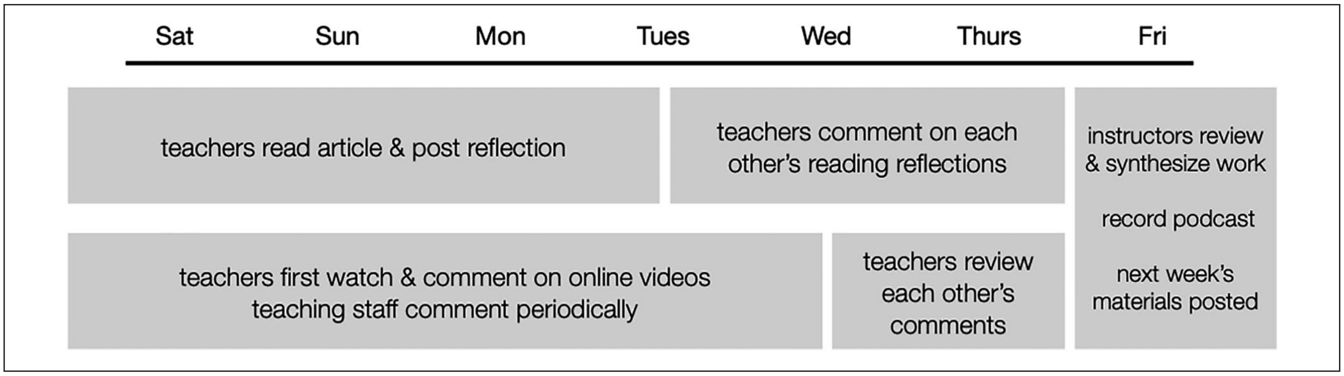

Figure 2. Depiction of the weekly protocol for the Engineering Pedagogy course.

Table 1. Description of Videos of Students' Engineering and Number of Teachers' Comments on Each.

Week	Description	Focus	2017 comments	2018 comments
Early videos				
Week 1	Fourth graders planning and sharing an initial prototype to help baby swans	Process	237	245
Week 3	Fifth graders describing how their structure stays cool under the sun	Ideas	245	227
Later videos				
Week 5	First-year college students designing a LEGO car to push candy	Process	235	193
Week 9	Third graders discussing how rotation of wheels help cars move forward	Ideas	349	241

showcased students' ideas about design mechanisms, in which students were explaining how a design worked, including scientific ideas related to a design's functionality. In Table 1, we present short descriptions and the number of comments teachers posted on each video.

Data Analysis

We first read through comments in the Spring17 course. We drew on prior coding frameworks (Luna & Sherin, 2017; Sherin & Han, 2004) to record what teachers noticed in their comments, adapting these frameworks to include teachers' noticing aspects of the engineering design process. Similar to Sherin and Russ (2014), we observed that teachers were not just noticing different aspects of the video, but they were situating these noticings differently. For instance, in noticing aspects of teaching, there were times in which teachers considered the moves made by the teacher in the video, and other times in which they were making connections to similar pedagogical issues in their classroom. We saw these different ways of noticing teaching as reflecting different ways of framing the video discussions.

In the next analytic phase, we focused on the video discussions of one group of five teachers. For each comment, we wrote descriptions to infer teachers' framing from what they noticed (Russ & Luna, 2013). These inferences were also informed by the work of Tannen (1993), in which she characterized evidence of participants' expectations about the nature of an activity. Drawing on her analysis, we considered what teachers chose to remark on and what they omitted in their comments, for example, whether they remarked on students' or teachers' activities. We also made note of when teachers used negative statements ("They're not thinking about the crane the way it is supposed to be used.") and evaluative adjectives or adverbs ("You can see that their explanations are simple."), which provided evidence of an evaluative framing. Connecting the work on epistemic stance (Kärkkäinen, 2003), we also considered whether and how teachers positioned themselves within the comment, for example, whether and how they indicated their relationship to their claims ("I think she means. . .," "She does understand. . .," "I like . . ."). We drew on these different forms of evidence to develop holistic descriptions of framing for each comment.

One researcher identified patterns across these comment descriptions and then generated, refined, and collapsed categories to develop a codebook for teachers' framing of video discussions. This codebook was further refined by coding video discussion of three other groups. We generally considered each video comment as the unit of analysis, but there

Table 2. What Teachers Focused on in Their Framing of Online Video Discussions.

	Student thinking	Student engagement	Pedagogy	Other
Spring17				
Week 1: Process	147 (62%)	21 (9%)	60 (25%)	9 (4%)
Week 3: Ideas	168 (69%)	7 (3%)	58 (24%)	12 (5%)
Week 5: Process	206 (88%)	6 (3%)	16 (7%)	7 (3%)
Week 9: Ideas	286 (82%)	17 (5%)	23 (7%)	23 (7%)
Spring18				
Week 1: Process	185 (77%)	13 (5%)	35 (14%)	12 (5%)
Week 3: Ideas	177 (78%)	5 (2%)	37 (16%)	8 (4%)
Week 5: Process	172 (89%)	11 (6%)	7 (4%)	3 (2%)
Week 9: Ideas	207 (86%)	8 (3%)	20 (8%)	6 (3%)

were times in which teachers seemed to shift in their framing within a single comment. For instance, one teacher commented: "She did all the commentating and has a really good idea about her design will work. It was good to note how the teacher fascilitated [sic] and asked questions so that the student could reflect on her own thinking to make sense of it." We coded this as two framings: at the start the teacher is evaluating a student's design idea and then shifts to remarking on the teacher moves. Other times teachers linked their observations of student thinking to teaching, for instance to justify a particular move: ". . .Sometimes [the students] cut each other off as they brainstorm ideas. I have a suggestion. Have one student state his ideas for two minutes, while the other student takes notes. Then have the students switch roles. . .." In this comment, the teacher attends to what the students are doing, noticing how they were interrupting each other in their interactions, but in service of suggesting pedagogical moves, so we kept the entire comment as indicating a single framing.

In the supplemental materials, we present the final codebook with examples of teachers' comments. Two researchers independently coded all comments (1,066 codes in Spring17; 906 in Spring18). Interrater reliability on coding each group's video discussion ranged from 84% to 91%, averaging 89%; all disagreements were resolved by consensus. To compare the distribution of teachers' comments across videos and groups of teachers, we first collapsed the codes into categories based on what teachers focused on in their framing. We then looked into how teachers framed the discussions when focusing on student thinking. To compare the distributions of teachers' comments from the start to the end of the course, we used chi-square tests, given the nonordinal relationships between the categories and the nonparametric nature of our dataset. We present percentages using the number of comments in each category divided by the total comments in a video discussion.

Findings

Our analysis revealed that, even at the start of the course, teachers were framing the online video discussions as opportunities to focus on student thinking. Furthermore, about half of teachers' comments were framed as making sense of student thinking in the Early Videos and less than a quarter were framed as evaluating. Despite this high proportion of initial comments focusing on student thinking, we found significant shifts between the distributions of teachers' framing in Early and Later Videos. By the Week 9 video, teachers were overwhelmingly taking up the video discussions as making sense of student thinking.

How Teachers Framed Online Video Discussions: Focus on Student Thinking From the Start

We first present our findings at a coarse-grained level, looking into what teachers focused on in their framings of the online video discussions (Table 2). We collapsed our framing codes into four bins: Student Thinking, Student Engagement, Pedagogy, or Other (which included comments about videotaping or for which there was not enough information).

Early in the course, the majority of teachers' comments focused on students' thinking (69% in Week 1, 73% in Week 3, averaging the two courses). In discussions that took place later in the course, with the same discussion prompts, an even greater percentage of comments were focused on student thinking (88% in Week 5, 84% in Week 9). For each course, the differences in distributions of teacher comments were statistically significant between Early Videos and Later Videos (Spring17: $\chi^2 = 71.5$ $p < .0001$, Spring18: $\chi^2 = 21.3$ $p < .0001$). Notably, we did not observe significant differences between videos focused on students' engineering design processes versus those focused on students' design ideas, except in comparing Early Videos in Spring 2017 ($\chi^2 = 8.7$ $p = .03$).

Differences in Framing of Student Thinking: Shifts Toward Making Sense and Away From Evaluating

For the framing categories focused on student thinking, teachers' comments were coded as making sense of student thinking, evaluating student thinking, or comparing students'

Table 3. Teachers' Framing of Student Thinking Early and Later in the Course.

	Early videos		Later videos	
	Week 1: Process	Week 3: Ideas	Week 5: Process	Week 9: Ideas
Spring17				
Making sense	85 (36%)	110 (45%)	164 (70%)	246 (70%)
Evaluating	53 (22%)	52 (21%)	40 (17%)	37 (11%)
Comparing	9 (4%)	6 (2%)	2 (1%)	3 (1%)
Spring18				
Making sense	117 (48%)	117 (52%)	143 (74%)	185 (76%)
Evaluating	61 (25%)	46 (20%)	29 (15%)	22 (9%)
Comparing	7 (3%)	14 (6%)	0 (0%)	0 (0%)

ideas or approaches with their own ideas. In Table 3, we present the number of comments coded in these three framings. The percentages represent the proportion of total coded comments in each week, not just the comments focused on student thinking.

In comparing the distributions of comments across the three framing categories focused on student thinking, we observed significant differences between discussions of Early Videos and Later Videos in both semesters (Spring17: $\chi^2 = 49.3$ $p < .0001$; Spring18[2]: $\chi^2 = 48.5$ $p < .0001$). In discussions of Early Videos, just under half of the total comments were framed as making sense of student thinking, while for Later Videos this proportion was closer to three-quarters. We also observed a corresponding decrease in the proportion of evaluative comments, from 22% to 25% in Week 1% to 9–11% in the Week 9 video discussion. Again, we did not observe significant differences between Process and Ideas videos, either early or later in the semester.

In the Week 1 video discussion, a sizable minority of the comments focused on student thinking were framed as evaluating or comparing students' thinking. As this video showcased students' design processes, teachers' evaluative comments were judging students' approaches to the design problems, the ways they communicated with each other, and their use of vocabulary. For instance, one teacher reflected on how a student shared his design: "The student in green clarified the materials—styrofoam instead of sticks. It would have been even better for him to have told why that choice was made." In this comment, the teacher is noticing useful aspects of engineering thinking by pointing to possibilities for reflective decision-making (Wendell et al., 2017). However, by pointing out what students should have done, she seems to be framing her role as evaluator, rather than seeking to make sense of students' approaches to design problem. Notably, in evaluating student thinking, teachers were often positive toward students' engineering but were still focused on making judgments.

In the Week 5 discussion, also on students' design processes, teachers had fewer evaluative comments and a greater proportion of comments indicating teachers were framing these discussions as opportunities to make sense of students' thinking. In comments making sense of students' design processes, teachers considered what students were doing as they planned or built their design and why they were making these moves. For instance, one teacher commented: "They are trying to figure out which lego pieces to use to hold the light sensor and the camera sensors on this prototype. They appear to be changing the lego pieces so they will not rub against each other causing friction in the process." In this comment, the teacher describes how the students were moving around the LEGO pieces and proposes possible reasons for these moves. Later in the discussion, another teacher points out an exchange between two students: "Josh's statement that a sensor is needed in the back shows understanding the challenge/problem framing. Sam's 'We do?' then immediate acceptance shows either trust in Josh's contribution, or skipping research." Again this teacher is noticing a key aspect of their design process but, unlike the example from Week 1, they are seeking to understand what and why Sam might be doing what he is doing. If framing the video discussions as evaluating, this teacher might have just labeled Sam as a "beginning designer" for skipping research, but instead they propose another interpretation that the student is trusting their collaborator's decision, thus making sense of the students' processes.

We saw similar shifts in how teachers were framing the videos showcasing students' ideas about designs. In Week 3 video, students expressed ideas about the movement of heat through their design. Again, a sizable minority of the comments focusing on student thinking were either evaluating students' ideas or comparing students' ideas with their own. These comments made judgments of students' ideas, for example: "It seems like at the beginning the student had the right idea. Hot air raises and cold air sinks, but here she says cold air is less dense. She seems to be confused on what the word "dense" means and how it relates to air molecules." In this comment, the teacher first assesses a student as having the "right idea"—evaluating their thinking based on its correctness. The teacher then points out another aspect of their idea, that cold air is "less dense." This student's idea can be seen as in conflict with their earlier idea that cold air sinks, if one assumes the student means density to be the amount of mass in a given volume. But there were indications that the student had a different meaning, for instance, she interchanged the words "thick" and "more dense" when talking about hot air, suggesting that she might be thinking about something like viscosity. However, in the above comment, the teacher did not engage in unpacking these possibilities of student meaning, instead labeling the student as confused, consistent with an evaluative framing.

By Week 9, most of the comments indicated that teachers were framing the discussions as making sense of students' ideas, with fewer comments evaluating or comparing with their own ideas; 90% of the comments were making sense of student's ideas. In many of the comments making sense of student thinking, teachers were offering interpretations and posing questions about students' meaning. For instance, one teacher commented: "By 'keep track of the floor' does he mean that as the wheels turn, the surface of the tires make contact with the floor? As in they roll?" The teacher quotes a student's word choice: "keep track of the floor" and suggests a possibility for what those words could mean and how it relates to the function of the car's wheels. This stands in contrast to the comment above from the Week 3 video in which a teacher dismissed a student's word choice without trying to ascertain the student's meaning.

Summary

A central goal of this study was to examine whether it was possible to design an online course in which teachers make sense of student thinking in video discussions. Our analyses show that teachers not only frequently attended to student thinking but also they developed stability in how they framed the discussions, overwhelmingly framing them as opportunities to make sense of student thinking in Later Videos. Given that we used different pairs of videos to compare Early and Late video discussions, we cannot discern whether the shifts in teachers' framing were due to differences in the videos or their learning in the course. Regardless, our analyses provide evidence that teachers can engage in productive video discussions in a designed asynchronous online course, similar to findings found in face-to-face settings in which facilitators can negotiate framing in real time.

One limitation is that our sample of teachers may not reflect general population, given that teachers enrolled in a graduate program in engineering education. However, program teachers had diverse teaching backgrounds; some teachers had extensive prior teaching experience and PD in engineering, while others were new to teaching this discipline. To mitigate this threat, we analyzed two different cohorts of teachers, showing repeatability in our findings.

Discussion

These findings add to a growing set of studies showing possibilities of online environments for teacher education. Although others have online video annotation tools for coaching or to support synchronous discussions (Choppin et al., 2020; Walkoe, 2015), we contribute a model for designing and facilitating video discussions in an entirely asynchronous course, recognizing the unique challenges that this context presents, given the lack of immediate back-and-forth exchanges and limited channels of communication.

This study shows the efficacy of this model and, by drawing on principles of design research, theorizes about the connections between the relationships between web-based technologies, facilitator and participant interactions, and teachers' learning (Dede et al., 2009; Moon et al., 2013). In particular, framing was a key construct we thread through course design, facilitation, and analysis. Building on extensive work on teacher noticing, we drew from the theory that highlights the reflexive relationship between noticing and framing (Figure 3): Learning to notice necessarily involves learning to frame teaching activities as opportunities to make sense of student thinking. This perspective focused our attention as designers, instructors, and analysts on how teachers were interpreting the kind of activity they were engaging in during the video discussions and the role they could play. Therefore, rather than cataloging every aspect of classroom activity that teachers noticed in their comments, we looked into how teachers were framing these discussions, getting a broader sense of how they were interpreting the kind of activity they were engaging in and the role they could play. At the same time, our analysis was informed by theoretical work from Russ and Luna—while we did not code for everything teachers noticed, our analysis drew on what they noticed to infer their framing.

In Figure 3, we also offer conjectures for our course design features fit within the relationship of teacher noticing and framing. We propose that the course-wide focus on student thinking and responsive podcasts worked primarily at the level of framing—they helped to negotiate the kind of activity that we hoped teachers would engage in during the video discussions. We suggest that the more specific design features of each week's discussion, the pairings of readings and videos and facilitators' comments, addressed *both* noticing and framing—they helped attune teachers to notice specific aspects of students' engineering work and to frame the video discussions as opportunities to make sense of that work.

Our theoretical perspective helps us understand how our video discussion model and findings connect to prior work. Although facilitation has been shown to be critical for video clubs in which facilitators can highlight, redirect, or press for reasoning in real time, the asynchronous nature of our video discussions meant that the facilitator comments on the video platform were less useful. Very few facilitator comments led to back-and-forth interactions, and there were no meaningful differences between groups with many facilitator comments

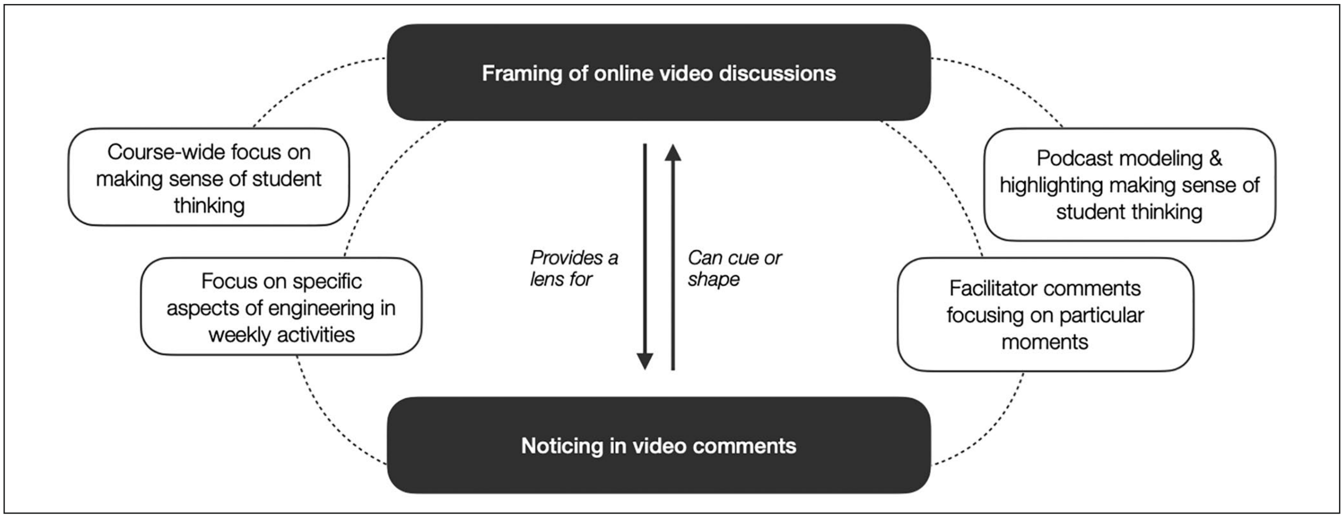

Figure 3. Depiction of the theorized relationship between framing and noticing, as well as how course design features fit within this relationship.

and those with little to no comments. Noting this, we iterated our design based on theoretical assumptions that responding to teachers' framing was critical to supporting their noticing and learning. In particular, the responsive podcasts represent a novel way to respond to how teachers were framing the video discussions, without real-time facilitation. Given the diverse engineering videos used each week, the podcasts were unlikely to help teachers notice the same things in the following week, which suggests that they primarily played a role in negotiating framing. Of course, we cannot isolate the role the podcasts played from the myriad factors that supported teacher framing, including the other design features embodying coherence and responsiveness, but highlight it as a unique tool in our design for facilitator-teacher interactions. In Figure 4, we highlight how our model for facilitating online video discussions differs from typical face-to-face models.

Our analysis also found that teachers were attending to student thinking even at the beginning of the course, which differs from much of the prior work on video clubs showing teachers starting with more of a focus on pedagogical moves and issues (Sherin & Han, 2004; van Es & Sherin, 2008). However, in a recent study, Luna and Sherin (2017) also found science teachers focused on student thinking from the start in their video club design. Although there are some meaningful differences in our designs, we argue that both had features to help teachers frame the video discussions as opportunities to make sense of student thinking. In Luna and Sherin's design, they asked teachers to select clips that showcase students' ideas, using technology that videotapes from the teacher's perspective. In our course, the videos of students' engineering work were paired with journal articles about learning engineering. Therefore, in both our course and Luna and Sherin's video club, there was a coherent set of resources available to attune teachers to student thinking prior to video discussions.

Finally, we note that the disciplinary content of the videos was engineering, while other video clubs and discussions have focused on mathematics or science. Prior work suggests that subject matter plays a role in teachers' attending to student thinking (Coffey & Edwards, 2015), and that teachers' orientations toward engineering can be different than science (Watkins et al., 2018). Since engineering design does not share the same history in schools (NRC, 2012) and generally has different institutional structures (e.g., no standardized tests) as other subjects, the difference in discipline likely matters for how teachers participate in the video discussions. Hence, there is a need for further exploration of online video discussions in other disciplines; can these findings be replicated in online video discussions focusing on mathematics or science? Furthermore, given that many engineering teachers, especially at the elementary level, are teaching multiple other subjects, there is a need to understand whether and how to support teachers' stability in attending to student thinking across disciplines. For instance, does the growing stability in making sense of student thinking in engineering we observed persist when teachers are discussing videos of students' engagement in other subjects?

Conclusion

In an asynchronous online course, we sought to support teachers to frame video discussions of students' engineering as opportunities to make sense of students' ideas, approaches, and perspectives in engineering design. Given the institutional and cultural emphasis in schools on evaluating students and highlighting their deficits, negotiating this framing with teachers can be challenging, even in face-to-face settings. By showing that it is possible for teachers to make sense of student thinking in online discussions, this study further opens up possibilities for considering how online teacher education

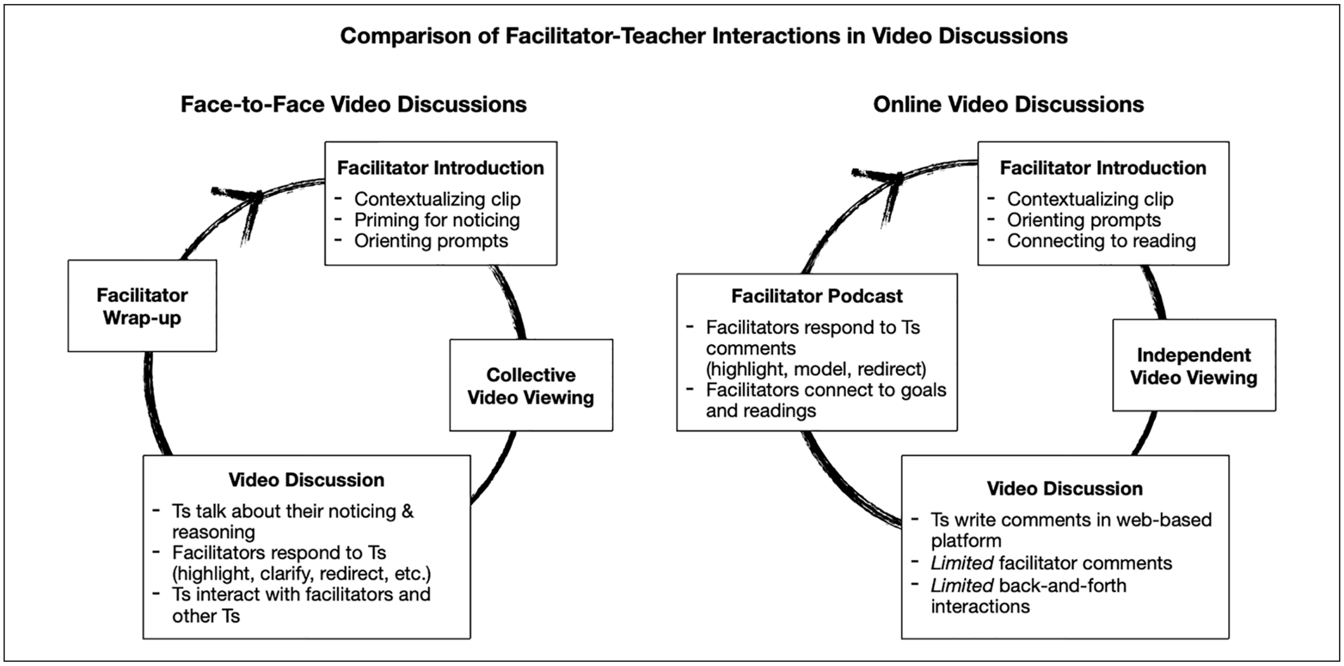

Figure 4. Depictions of video discussion cycles in typical face-to-face video discussions and in the Engineering Pedagogy course.

can support teachers' reasoning and practice. We suggest that designing for teachers' framing may be critical not just for online video discussions, but other online professional learning activities that are seeking to broaden or challenge what typically takes place in classrooms. When asking teachers to engage in activities that may be unfamiliar or even in tension with institutional and cultural norms around teaching, there is a need to consider how to help teachers frame their participation. Moreover, the recent shift to online education during the COVID-19 pandemic heightens the need for continued research in this area that centers constructivist and equity-focused teacher learning, while harnessing the accessibility and flexibility of online environments.

Acknowledgments

The authors thank Yangsook Kim for her contributions to preliminary data analyses. We also acknowledge Miriam Sherin, Andy Elby, and Rebecca Swanson for their feedback on earlier drafts of this work.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by National Science Foundation under grant DRL-1720334.

ORCID iD

Jessica Watkins https://orcid.org/0000-0003-4975-1086

Supplemental Material

Supplemental material for this article is available online.

Notes

1. Notably, there were moments in which TAs themselves took up a different framing of the video discussions, to explore teacher moves or broader pedagogical issues. In the Spring18 cohort, one group had a facilitator make several of these comments.
2. Because in Spring18, there were no comments coded as Comparing in Late Videos, we performed a 2×2 chi-square test.

References

Bang, M., Brown, B., Calabrese Barton, A., Rosebery, A. S., & Warren, B. (2017). Toward more equitable learning in science: Expanding relationships among students, teachers, and science practices. In C. V. Schwarz, C. Passmore, & B. J. Reiser (Eds.), *Helping students make sense of the world using next generation science and engineering practices* (pp. 33–58). NSTA Press.

Bateson, G. (1972). *Steps to an ecology of mind*. Balentine Books.

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, *24*(2), 417–436. https://doi.org/10.1016/j.tate.2006.11.012

Borko, H., Jacobs, J., Seago, N., & Mangram, C. (2014). Facilitating video-based professional development: Planning and orchestrating productive discussions. In Y. Li, E. A. Silver, & S. Li (Eds.), *Transforming mathematics instruction* (pp. 259–281). Springer.

Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), *APA handbook of research methods in psychology, Vol. 2. Research designs: Quantitative, qualitative,* *neuropsychological, and biological* (pp. 57–71). American Psychological Association.

Choppin, J., Amador, J. M., Callard, C., Carson, C., & Gillespie, R. (2020). Synchronous online model for mathematics teachers' professional development. In P. Wachira & J. Keengwe (Eds.), *Handbook of research on online pedagogical models for mathematics teacher education* (pp. 176–202). IGI Global. https://doi.org/10.4018/978-1-7998-1476-4.ch011

Coffey, J. E., & Edwards, A. R. (2015). The role subject matter plays in prospective teachers' responsive teaching practices in elementary math and science. In A. D. Robertson, R. E. Scherr, & D. Hammer (Eds.), *Responsive teaching in science and mathematics* (pp. 145–161). Routledge.

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

Collison, G., Elbaum, B., Haavind, S., & Tinker, R. (2000). *Facilitating online learning: Effective strategies for moderators*. Atwood Publishing.

Dede, C., Eisenkraft, A., Frumin, K., & Hartley, A. (2016). *Teacher learning in the digital age: Online professional development in STEM education*. Harvard Education Press.

Dede, C., Ketelhut, D. J., Whitehouse, P., Breit, L., & McCloskey, E. (2009). A research agenda for online teacher professional development. *Journal of Teacher Education*, *60*(1), 8–19. https://doi.org/10.1177/0022487108327554

Erickson, F. (2011). On noticing teacher noticing. In M. G. Sherin, V. R. Jacobs, & R. A. Philipp (Eds.), *Mathematics teacher noticing* (pp. 47–64). Routledge.

Fishman, B., Konstantopoulos, S., Kubitskey, B. W., Vath, R., Park, G., Johnson, H., & Edelson, D. C. (2013). Comparing the impact of online and face-to-face professional development in the context of curriculum implementation. *Journal of Teacher Education*, *64*(5), 426–438. https://doi.org/10.1177/0022487113494413

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

Gaudin, C., & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Educational Research Review*, *16*, 41–67. https://doi.org/10.1016/j.edurev.2015.06.001

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. Harvard University Press.

Gresalfi, M., Martin, T., Hand, V., & Greeno, J. (2009). Constructing competence: An analysis of student participation in the activity systems of mathematics classrooms. *Educational Studies in Mathematics*, *70*(1), 49–70. https://doi.org/10.1007/s10649-008-9141-5

Hammer, D., & van Zee, E. (2006). *Seeing the science in children's thinking: Case studies of student inquiry in physical science*. Heinemann.

Haverly, C., Calabrese Barton, A., Schwarz, C. V., & Braaten, M. (2020). "Making space": How novice teachers create opportunities for equitable sense–making in elementary science. *Journal of Teacher Education*, *71*(1), 63–79. https://doi.org/10.1177/0022487118800706

Kang, H., & Anderson, C. W. (2015). Supporting preservice science teachers' ability to attend and respond to student thinking by design. *Science Education*, *99*(5), 863–895. https://doi.org/10.1002/sce.21182

Kärkkäinen, E. (2003). *Epistemic stance in English conversation: A description of its interactional functions, with a focus on "I think."* John Benjamins.

Kazemi, E., & Franke, M. L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, *7*, 203–235.

Koc, Y., Peker, D., & Osmanoglu, A. (2009). Supporting teacher professional development through online video case study discussions: An assemblage of preservice and inservice teachers and the case teacher. *Teaching and Teacher Education*, *25*(8), 1158–1168. https://doi.org/10.1016/j.tate.2009.02.020

Lau, M. (2010). *Understanding the dynamics of teacher attention: Case studies of how high school physics and physical science teachers attend to student ideas*. University of Maryland.

Levin, D. M., Hammer, D., & Coffey, J. E. (2009). Novice teachers' attention to student thinking. *Journal of Teacher Education*, *60*(2), 142–154. https://doi.org/10.1177/0022487108330245

Llinares, S., & Valls, J. (2009). The building of pre-service primary teachers' knowledge of mathematics teaching: Interaction and online video case studies. *Instructional Science*, *37*, 247–271. https://doi.org/10.1007/s11251-007-9043-4

Louie, N. L. (2018). Culture and ideology in mathematics teacher noticing. *Educational Studies in Mathematics*, *97*, 55–69. https://doi.org/10.1007/s10649-017-9775-2

Luna, M. J., & Sherin, M. G. (2017). Using a video club design to promote teacher attention to students' ideas in science. *Teaching and Teacher Education*, *66*, 282–294. https://doi.org/10.1016/j.tate.2017.04.019

Moon, J., Passmore, C., Reiser, B. J., & Michaels, S. (2013). Beyond comparisons of online versus face-to-face PD: Commentary in response to Fishman et al., "Comparing the impact of online and face-to-face professional development in the context of curriculum implementation." *Journal of Teacher Education*, *65*(2), 172–176. https://doi.org/10.1177/0022487113511497

National Research Council (NRC). (2012). *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. National Academies Press.

Nemirovsky, R., & Galvis, A. (2004). Facilitating grounded online interactions in video-case-based teacher professional development. *Journal of Science Education and Technology*, *13*(1), 67–79. https://doi.org/10.1023/B:JOST.0000019639.06127.67

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal*, *44*(4), 921–958. https://doi.org/10.3102/0002831207308221

Pierson, J. L. (2008). *The relationship between patterns of classroom discourse and mathematics learning*. University of Texas.

Radoff, J., Robertson, A. D., Fargason, S., & Goldberg, F. (2018). Responsive teaching and high-stakes testing. *Science & Children*, *55*(9), 88–92.

Robertson, A. D., Scherr, R. E., & Hammer, D. (2015). *Responsive teaching in science and mathematics*. Routledge.

Rosebery, A. S., Warren, B., & Tucker-Raymond, E. (2016). Developing interpretive power in science teaching. *Journal of Research in Science Teaching*, *53*(10), 1571–1600. https://doi.org/10.1002/tea.21267

Rovai, A. P. (2007). Facilitating online discussions effectively. *Internet and Higher Education*, *10*(1), 77–88. https://doi.org/10.1016/j.iheduc.2006.10.001

Russ, R. S. (2018). Characterizing teacher attention to student thinking: A role for epistemological messages. *Journal of Research in Science Teaching*, *55*(1), 94–120. https://doi.org/10.1002/tea.21414

Russ, R. S., & Luna, M. J. (2013). Inferring teacher epistemological framing from local patterns in teacher noticing. *Journal of Research in Science Teaching*, *50*(3), 284–314. https://doi.org/10.1002/tea.21063

Russ, R. S., & Sherin, M. G. (2013). Using interviews to explore student ideas in science. *Science Scope*, *36*(5), 19–23.

Sandoval, W. A. (2004). Developing learning theory by refining conjectures embodied in educational designs. *Educational Psychologist*, *39*(4), 213–223. https://doi.org/10.1207/s15326985ep3904_3

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

Sherin, M. G., & Han, S. Y. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education*, *20*(2), 163–183. https://doi.org/10.1016/j.tate.2003.08.001

Sherin, M. G., Linsenmeier, K. A., & van Es, E. A. (2009). Selecting video clips to promote mathematics teachers' discussion of student thinking. *Journal of Teacher Education*, *60*(3), 213–230. https://doi.org/10.1177/0022487109336967

Sherin, M. G., & Russ, R. S. (2014). Teacher noticing via video: The role of interpretive frames. In B. Calandra & P. J. Rich (Eds.), *Digital video for teacher education* (pp. 11–28). Routledge.

Sherin, M. G., & van Es, E. A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education*, *60*(1), 20–37. https://doi.org/10.1177/0022487108328155

Star, J. R., & Strickland, S. K. (2008). Learning to observe: Using video to improve preservice mathematics teachers' ability to notice. *Journal of Mathematics Teacher Education*, *11*(2), 107–125. https://doi.org/10.1007/s10857-007-9063-7

Sun, J., & van Es, E. A. (2015). An exploratory study of the influence that analyzing teaching has on preservice teachers' classroom practice. *Journal of Teacher Education*, *66*(3), 201–214.

Tannen, D. (1993). What's in a frame? Surface evidence for underlying expectations. In D. Tannen (Ed.), *Framing in discourse* (pp. 14–56). Oxford University Press.

Tannen, D., & Wallat, C. (1993). Interactive frames and knowledge schemas in interaction: Examples from a medical examination/interview. In D. Tannen (Ed.), *Framing in discourse* (pp. 57–76). Oxford University Press.

Tekkumru-Kisa, M., & Stein, M. K. (2015). Learning to see teaching in new ways: A foundation for maintaining cognitive demand. *American Educational Research Journal*, *52*(1), 105–136. https://doi.org/10.3102/0002831214549452

Tekkumru-Kisa, M., & Stein, M. K. (2017). A framework for planning and facilitating video-based professional development. *International Journal of STEM Education*, *4*(28), 1–18. https://doi.org/10.1186/s40594-017-0086-z

Thompson, J., Hagenah, S., Kang, H., Stroupe, D., Braaten, M., Colley, C., & Windschitl, M. (2016). Rigor and responsiveness in classroom activity. *Teachers College Record*, *118*(1), 1–58.

Valtorta, C. G., & Berland, L. K. (2015). Math, science, and engineering integration in a high school engineering course: A qualitative study. *Journal of Pre-College Engineering Education Research*, *5*(1), 15–29. https://doi.org/10.7771/2157-9288.1087

van Es, E. A. (2009). Participants' roles in the context of a video club. *The Journal of the Learning Sciences*, *18*(1), 100–137. https://doi.org/10.1080/10508400802581668

van Es, E. A., Hand, V., & Mercado, J. (2017). Making visible the relationship between teachers' noticing for equity and equitable teaching practice. In E. O. Schack, M. H. Fisher, & J. A. Wilhelm (Eds.), *Teacher noticing: Bridging and broadening perspectives, contexts, and frameworks* (pp. 251–270). Springer. https://doi.org/10.1007/978-3-319-46753-5

van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, *24*(2), 244–276. https://doi.org/10.1016/j.tate.2006.11.005

van Es, E. A., & Sherin, M. G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education*, *13*(2), 155–176. https://doi.org/10.1007/s10857-009-9130-3

van Es, E. A., Tunney, J., Goldsmith, L. T., & Seago, N. (2014). A framework for the facilitation of teachers' analysis of video. *Journal of Teacher Education*, *65*(4), 340–356. https://doi.org/10.1177/0022487114534266

Walkoe, J. (2015). Exploring teacher noticing of student algebraic thinking in a video club. *Journal of Mathematics Teacher Education*, *18*(6), 523–550. https://doi.org/10.1007/s10857-014-9289-0

Watkins, J., McCormick, M. E., Milto, E., Portsmore, M., Spencer, K., Wendell, K. B., & Hammer, D. (2018). Data-based conjectures for supporting responsive teaching in engineering design with elementary teachers. *Science Education*, *102*(3), 548–570. https://doi.org/10.1002/sce.21334

Wendell, K. B., Watkins, J., & Johnson, A. W. (2016). *Noticing, assessing, and responding to students' engineering: Exploring a responsive teaching approach to engineering design* [Conference session]. Proceedings of the 123rd American Society for Engineering Education Annual Conference and Exposition, New Orleans, LA, United States.

Wendell, K. B., Wright, C., & Paugh, P. (2017). Engineering design as reflective decision-making: How elementary school students make collaborative planning and redesign choices during formal engineering learning experiences. *Journal of Engineering Education*, *106*(3), 356–397.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878–903. https://doi.org/10.1002/sce.21027

Author Biographies

Jessica Watkins is an assistant professor of science education at Vanderbilt University. Her scholarship is motivated by the need to foster more responsive and expansive learning environments for science and engineering. She designs for and studies these environments in K-16 classrooms and through teacher education.

Merredith Portsmore is the director of the Tufts Center for Engineering Education and Outreach, as well as a research associate professor. Her research interests focus on engineering education looking into teacher education, broadening engineering participation through outreach, and online learning pedagogies. She is the founder of STOMP, LEGO Engineering.com, and the online Teacher Engineering Education Program.