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Mathematics teachers' self-captured video and opportunities for learning

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Abstract Numerous video-based programs have been developed to support mathematics teachers in reflecting on and examining classrooms interactions without the immediate demands of instruction. An important premise of such work is that teacher learning occurs at the time that the video is viewed and discussed with teachers. Recent advances in technology, however, offer new approaches for the use of video with teachers. We claim that these new technologies provide important opportunities for teacher learning prior to the viewing and discussion of video with colleagues. In particular, we believe that important teacher learning can occur from the activities of (1) capturing video from one's own classroom and (2) selecting clips to share with others. The goal of this article is to introduce key strategies that three groups of middle and high school mathematics teachers use prior to, during, and after instruction as they engage in this work. We believe that increased attention to these strategies is necessary in order to better understand how to support teacher learning in the context of new digital technologies.

Keywords Teacher learning · Video · Professional development · Teacher cognition

Introduction

Video has been a central part of efforts to support mathematics teacher learning for over twenty years. Much of this work has been driven by the idea that video provides teachers with opportunities to examine and reflect on classroom interactions, while free from the immediate demands of teaching. Researchers have documented a range of learning

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outcomes with video including increased motivation and mathematical knowledge for teaching, as well as changes in teachers' instruction (Borko et al. 2008; Seidel et al. 2011; Sherin and van Es 2009). At the same time, research has emphasized that video in and of itself does not promote learning; rather, it is the use video in particular ways that has the potential to support teacher learning (Blomberg et al. 2013).

Numerous video-based programs have been developed with this goal in mind. Many programs provide a set of published video excerpts with facilitation material to direct teachers' analyses (e.g., Corwin et al. 1996; Schifter et al. 1999; Seago et al. 2004). In these cases, a great deal of effort has typically gone into selecting and sequencing the video clips. Some also provide explicit analytic tools to guide teachers' analysis of video (Goldsmith and Seago 2012). Other programs have been developed with the goal of using video from participating teachers' own classrooms as the source of discussion (Grant et al. 2001; van Es and Sherin 2008). These programs may also provide tools that guide teachers' analysis. An example is Borko and colleagues' Problem Solving Cycle, which asks participants to first analyze students' thinking in a video and later analyze the role of the teacher (Borko et al. 2015). In all of these programs, the central mechanism through which teachers are expected to learn from video is through watching and discussing video excerpts. In other words, the presumption is that teacher learning occurs *at the time that the video is viewed and discussed* by teachers.

Recent advances in technology offer new approaches for the use of video with teachers. In particular, the wide accessibility of small digital recording devices makes it increasingly feasible for teachers to capture fairly high-quality video from their own classes. In addition, the development of new web-based tools for video storage and annotation means that teachers can more easily upload and share videos with peers. On the one hand, we believe these advancements are important because of the opportunities they open up for teachers to collaborate with colleagues, locally and at a distance, around video. But in addition, we claim that these new technologies provide new important opportunities for teacher learning *prior to the viewing and discussion of video with colleagues*. In particular, we contend that important teacher learning can occur from the activities of (a) capturing video from one's own classroom and (b) selecting clips to share with others. The goal of this article is to articulate the theory behind these learning opportunities as well as to provide several illustrative examples. In doing so, we introduce three key components of the video clip capture and selection process. We believe that increased attention to these components is necessary in order to better understand how to support teacher learning in the context of new digital technologies.

Perspectives

Capturing classroom lessons on video

As a tool for capturing classroom interactions, video is unparalleled. Even if a video camera is simply put on a tripod and turned on, we can have what feels like a rich record of what transpired, one that, when viewed, can transport us back to the classroom events. However, not all videos of a classroom event are equivalent; rather any video reflects a particular perspective on what took place (Blomberg et al. 2013; Goldman-Segall 1998). This perspective arises from all of the choices that must be made in capturing the video, choices that include the positions of the camera and microphone, as well as the moments when the video is started and stopped. These choices can profoundly affect our impression of what transpired by highlighting some aspects of instruction while obscuring others (Sherin and Dyer 2017; van Es et al. 2015).

Throughout the 1990s, researchers frequently recorded classrooms from the back of the room. This often led to videos that highlighted the teacher and obscured students. Beginning in the early 2000s, some began to advocate for videotaping from the side of the classroom in order to more equally capture faces of both the teacher and students. At the same time, video prepared for published professional development materials often used more elaborate recording configurations that made use of multiple cameras and microphones, allowing for multiple perspectives to be taken when watching the video. And these advancements have continued. For example, in one line of research, Roy Pea and colleagues developed a system that allowed for 360 degree recording of classroom interactions (Pea 2006). Furthermore, viewers could literally "dive into" the video upon later viewing, changing the angle from which the recorded classroom was viewed. The intended purpose of this technology was to give the viewer more control over what and where to look in the classroom.

As it becomes more common for teachers take up the task of recording their own classrooms, the logistics of how to record a lesson become particularly important to consider. This importance is further heightened by rapid changes in the video technology available to teachers. In the past, it was common for teachers to set up a (rather large and heavy) video camera and tripod in their classroom, start recording shortly before a lesson began, and stop the camera at the end of the lesson. Now, the world of the classroom is saturated with video recording technologies, making video capturing financially feasible and easier logistically. Many teachers, and even students, have a video camera in their smartphones, with a large capacity to capture video and even upload that video to remote storage. This opens up the possibility for teachers to make complex, on-the-fly decisions about what to record and how to record it.

At the present time, we know little about how this on-the-fly decision-making works, or its impact. What type of moments do teachers tend to capture? What does it take to capture video in this way? Does this recording interfere or enhance teachers' ongoing instructional activity? Does this process promote teacher learning?

Selecting clips for teacher learning

Although capturing classroom video has become easier and more common, we believe that selecting video to watch and share is still a significant task. Researchers have often spent hours or even days combing through video in order to select a short clip to show a group of teachers for the purpose of discussion and analysis. In many cases, researchers have been guided only by very general principles as to the kinds of clips to look for, for example a clip that "reveals an interesting student strategy" or that shows the "teacher and student talking about math." Having engaged in such work ourselves, we have found it to be decidedly complex. In one related line of research, we introduced three dimensions that are important to consider in selecting video excerpts for the purpose of having teachers discuss student mathematical thinking (Sherin et al. 2009). First, we found that productive video clips included extensive *windows* into student thinking, that is, access to students' ideas through student talk, writing, and/or gestures. Second, we found that clips that were high in terms of the *depth* of student mathematical thinking portrayed served to better promote productive discussions among teachers. Video clips that were high in depth captured students engaged in problem solving at a conceptual level, often using innovative strategies. Third, we found that clips that were low in *depth*, meaning student thinking was mainly routine and procedural, and were also low in *clarity*, meaning student methods were not easily understood at first glance, were also the source of productive teacher conversations.

This prior work serves to highlight the difficulty of selecting video clips that will provide a productive basis for discussion. We propose that this complexity also factors into how teachers select clips. However, we should not assume that the task faced by teachers is the same as the one faced by researchers. In addition to having less time available, teachers are likely to view video with a different lens than researchers (Sherin 2001). These lenses employed by teachers, and the process they go through in selecting videos, are thus important foci for research.

Video as a resource for developing teacher noticing

The goal of this article is to examine the ways that capturing and selecting video from one's classroom provides opportunities for teacher learning. Of course, there are many axes along which a teacher might learn (Russ et al. 2016). In our work, we are particularly interested in teacher learning as it relates to the development of teacher *noticing* (Sherin and Han 2004). Furthermore, there is a prima facie case to be made that teacher noticing is an attribute of teaching ability that is likely to be impacted by the activities of recording and selecting clips.

More and more often, teacher noticing is cited as a key component of teaching expertise (Sherin et al. 2011). The classroom is a complex environment with many things happening at once. Thus, a teacher must make constant, important decisions about where to focus her attention (Schoenfeld 2010; Sherin and Star 2011). Mathematics teaching, in particular, places heavy demands on teacher noticing. Mathematics teachers are expected to be responsive to students' ideas and to adapt instruction, at least in part, based on how a lesson unfolds in the moment. Such adaptability relies in large part on teacher's noticing expertise (Dyer and Sherin 2016).

Over the past decade, an increasing number of researchers have examined the nature of teacher noticing. Our work in this area focuses on two key components of teacher noticing: (a) *selective attention* involves identifying key features of classroom interactions and (b) *knowledge-based reasoning* involves the ability to make sense of those interactions by drawing on one's knowledge and experience. Other researchers also distinguish between *attending* and *interpreting* (e.g., Goldsmith and Seago 2011; Jacobs et al. 2011) while recognizing the interconnectedness of these processes. For example, Sherin and Star (2011) and Sherin and Russ (2014) emphasize that attending and interpreting likely happen simultaneously to some degree, as what a teacher attends to influences her reasoning about the noticed event and in addition, how a teacher makes sense of classroom interactions will influence what events tend to stand out to that teacher.

A range of research documents that watching and discussing video can help teachers learn to attend to and make sense of classroom interactions in new ways, ways that are consequential for instruction. We have examined this issue in the context of video clubs, in which groups of teachers watch and discuss excerpts of videos from their classrooms with colleagues in order to examine students' mathematical thinking (Dyer 2013; Sherin and Han 2004; Sherin 2007). We found that teachers attended closely to students' mathematical thinking in the videos presented and developed new ways to diagnose and interpret students' ideas as they discussed the videos. Subsequently in instruction, teachers were seen attending more closely to students' ideas and using similar strategies to make sense of the ideas students raised during instruction (van Es and Sherin 2010). Similarly, Borko et al. (2015) demonstrate teachers' increased attention to the specifics of student thinking during video-based discussions and becoming better able to understand and build on students' ideas while teaching as well.

In all of this prior work, teachers learned from viewing and discussing video with peers and a facilitator. The current article extends such work and asks whether capturing and selecting video from one's own classroom provides similar opportunities for teacher learning, and for the development of teacher noticing in particular.

Research design

Over the past 10 years, we have been studying teachers, across multiple contexts, as they discuss video they collected from their own classrooms. The goal of this varied work has been both to understand the nature of teacher noticing as well as to understand how to expand the work of video clubs as a context for teacher learning. As we have reported elsewhere (Sherin et al. 2009), in our prior work, researchers typically videotaped in participating teachers' classrooms and selected clips to show at the meetings. However, more recently we have been investigating the feasibility of teachers capturing and selecting the video. In doing so, we investigated ways to minimize some of the burden of having to review video of whole lessons following instruction, something that we thought would be prohibitive for teachers given their demanding schedules. In particular, we explored the possibility of having teachers select, prior to a lesson, a segment of a lesson to record that they thought would be a likely candidate for portraying student mathematical thinking. In addition, we experimented with technology that allowed teachers to indicate, during instruction, key segments of instruction. In this case, teachers would not have to review an entire lesson and could instead, simply go to those moments that had been marked during the lesson.

For the purposes of this article, we draw on our work with three groups of mathematics teachers, 14 teachers in all (Table 1). The groups engaged in different video capture tasks, used different equipment, and participated in different numbers of meetings related to

Table 1 Comparison of data sources

	Baxter High School	Midwest University	Metro School District
Teacher population	Four high school mathematics teachers	Five secondary pre-service mathematics teachers	Five middle and high school mathematics teachers
Task	Capture and select clips for video club discussions of student thinking	Capture and select clips of student substantive mathematical thinking	Tag moments of student mathematical thinking
Frequency of task	Five lessons per teacher	Three lessons per teacher	Five lessons per teacher
Equipment	Small digital camera on tripod with external microphone (e.g., Kodak Playtouch)	Small digital camera on tripod with external microphone (e.g., Kodak Playtouch)	Camera worn on bill of hat during instruction (e.g., POV 1.5)
Data	Transcripts of interviews and meetings	Written reflections from course assignments	Transcripts of interviews

video capture. However, all three groups of teachers had a similar focus: teachers were asked to capture short video clips of student mathematical thinking. By "student mathematical thinking" we had in mind moments during instruction when students were talking substantively about mathematics—for example, working on a problem with peers, asking questions about procedures or methods, or sharing solutions with a partner or with the whole class. Of course, every moment of classroom instruction may not include instances of "student mathematical thinking." As will become clear, this was one of the challenges facing the teachers.

Our decision to focus on video of student mathematical thinking builds on prior research that highlights that when mathematics teachers pay close attention to students' ideas, the opportunities for student learning increase (e.g., Jacobs et al. 2007). Furthermore, as mentioned previously, our own research on teacher learning in video clubs has documented that viewing and discussing videos of student thinking can help to develop teacher noticing of students' mathematical thinking in ways that are consequential for instruction (Sherin and van Es 2009, van Es and Sherin 2010). As such, this study highlights the opportunities for teacher learning about student mathematical thinking when capturing and selecting video from one's classroom.

Veteran teachers at Baxter High School

Four mathematics teachers from Baxter High School met five times over a two-month period to discuss how to collect video clips of students' mathematical thinking to share with colleagues for the purposes of a video club. In the first meeting, the teachers participated in a shortened video club in which they watched and discussed a video clip from a mathematics class selected by the researcher. The discussion was facilitated by the second author as a way to help familiarize the teachers with the video club format and with the explicit focus on students' mathematical thinking. The remaining meetings focused on participants' experiences capturing clips that would support productive video club discussions around student mathematical thinking and the viability of different types of clips to prompt interesting discussion among teachers. Following each meeting, the teachers were asked to capture video of their classroom and select two or three 4–6 min clips of students' mathematical thinking that they thought would be interesting to discuss with colleagues. To do so, the teachers used small digital cameras with an external microphone and a tripod and were encouraged to record only selected portions of their lessons.

The data collected include videos of the four meetings related to capturing video and audiotaped interviews with the teachers about their experiences capturing video. Five brief 10-min interviews were conducted with each teacher following each class session during which they captured clips, as well as a final interview after the last group meeting. The interviews focused on the teachers' decision making around capturing video, their initial assessment of how well the capturing went, and whether capturing video had an influence on their teaching.

Prospective teachers at Midwest University

Five prospective teachers, enrolled in a secondary mathematics teacher preparation program at *Midwest University,* met weekly during their 10-week student teaching field experience co-facilitated by the second author. As part of their coursework, the teachers were asked to capture video clips of substantive student mathematical thinking on three occasions. In particular, the teachers were asked to choose a portion of a lesson to record and to then review the video and select a 4–6 min excerpt that best portrayed students' substantive mathematical thinking. As with the Baxter High School teachers, the prospective teachers used small digital cameras with an external microphone affixed to a tripod to record in their classrooms.

The data include written reflections completed by the teachers related to their experiences capturing video. Specifically, teachers were asked to discuss their decisions about what to capture on video as well as the extent to which they believe they successfully captured student thinking. In addition, the teachers were asked to complete a written analysis of the student thinking in their selected clips and to reflect on how capturing video might influence their teaching.

Veteran teachers in Metro School District

The third context involved five middle and high school mathematics teachers from a large urban school district in the USA. Each teacher used a small digital camera that was worn on the brim of a hat to capture video from their classrooms. The camera featured a separate recording module that could be held or attached to a belt. While the camera recorded, the teachers could press a button on the recording module to "mark" specific moments of instruction.[1] Later, these moments could be easily accessed in the resulting digital video file. In their capturing of clips, the teachers focused on capturing "interesting or important moments of student math thinking." Each teacher completed this activity during five lessons.

The data consist of individual interviews with each teacher following each use of the camera. In the interviews, teachers were asked why they had captured each moment and what was interesting about the student thinking portrayed. The teacher was able to review each moment on a computer if needed.

Analysis

Qualitative methods formed the basis for analysis which was comprised of three main phases. In the first phase, the meetings and interviews with the veteran teachers were transcribed. Subsequently, the data were reviewed by a team of researchers. Initial impressions confirmed that capturing video and selecting clips was in fact a complex activity for many teachers. In particular, across the data sources, we noted that teachers engaged in a range of different activities to support their efforts to capture and select video clips, and that these activities seemed to differ according to *when* they took place—prior to instruction as teachers planned for video capture, during instruction, which often coincided with video capture, or following instruction. To investigate this further, in the second phase of analysis, a subset of transcripts and written reflections were examined in order to characterize the range of comments made by the teachers regarding their efforts to capture video and select clips before instruction, during instruction, and following instruction. Through an iterative process of open coding (Strauss and Corbin 1998), we identified and defined six distinct strategies used by the teachers as they worked to capture and select video from their classrooms (Table 2). The strategies will be discussed in detail in "Modeling the video clip capture and selection process" section.

[1] One teacher used a slightly different camera that saved the previous minute of video when the "tag" button was pressed.

Table 2 Strategies used by teachers at different time periods to capture and select video

Prior to instruction	
Anticipate student thinking	Predict where in a lesson student mathematical thinking will be visible
Prepare to notice	Predict what student mathematical thinking will look like and plan to watch for it
During instruction	
Focused noticing	Identify interesting student mathematical thinking during instruction
Adjust instruction	Take action during instruction to promote visible student mathematical thinking
After instruction	
Reflective noticing	Realize a previous event revealed interesting student mathematical thinking
Assess potential clips	Consider extent of visible student mathematical thinking in video excerpts

In the final phase of analysis, two researchers coded the data with these six strategies in mind. Transcripts of the interviews and meetings were examined, turn by turn, for evidence of teachers referencing any of the strategies. The written reflections were coded at the level of a paragraph. Each turn or paragraph could be assigned multiple codes as appropriate. One researcher coded the data for 11 teachers; a second researcher coded data for eight of the teachers. Coding of the five overlapping teachers was examined for inter-rater reliability which exceeded 85% across all six strategies. To provide a sense of the frequency with which the strategies were used, we identified the strategies that the teachers reported using on each occasion when they videotaped in their classroom. For example, as shown in Table 3, the Baxter High School teachers reported using the strategy "Anticipate Student Thinking" during all 20 of the occasions in which they recorded in their classrooms (5 times per teacher). In contrast, they reported using the strategy "Prepare to notice" in only 15 of the lessons during which they captured video.

Modeling the video clip capture and selection process

A central goal of this paper is to articulate a framework that outlines key strategies that teachers use as they attempt to capture and select video from their own classrooms and the extent to which such strategies provide learning opportunities for teachers. Clearly the ways that an individual teacher captures and selects video excerpts likely depends on a variety of factors including the teacher's knowledge of the subject matter, experiences with the particular lesson, interactions with students, and more, not to mention the specific purpose a teacher has in mind for using the clip. Nevertheless, we have found that there are similarities across teachers at each of three time periods. Specifically, prior to instruction, as teachers worked to determine what part of a lesson to videotape, they engaged in two kinds of decision-making processes. First, they conducted a sort of simulation of a lesson in order to locate the nexus of student thinking. In addition, they anticipated particular kinds of interactions or activities that they would like to pay attention to, should they take place during instruction. During instruction, teachers applied two other strategies to support their efforts to capture and selecting video clips. One strategy consisted of teachers deciding in the moment of instruction that an interaction was "video-worthy." Another

Table 3 Reported strategy use by teachers during video capture activities

	Prior to instruction		During instruction		After instruction	
	Anticipate student thinking	Prepare to Notice	Focused noticing	Adjust instruction	Reflective noticing	Assess potential clips
Baxter High School (20 total video captures)	20	15	18	17	15	12[a]
Midwest University (15 total video captures)	15	11	15	11	7	15
Metro School District (25 total video captures)	13	18	25	18	18	25
Total across site (60 video captures)	48 (80%)	44 (73%)	58 (97%)	46 (77%)	35 (58%)	52 (87%)

[a] Baxter High School teachers did not always view the captured video prior to the interview

approach involved adapting instruction in the midst of teaching in order to promote the kind of activity that they wanted to capture on video. Finally, after teaching a lesson, teachers also considered issues of capturing and selecting video excerpts in particular ways. Here, teachers identified an event or interaction that had not been captured on video, but that the teacher realized would have been appropriate to record. In addition, teachers reviewed captured video and reevaluated what took place during instruction.

To be clear, the fact that teachers engaged in work around capturing and selecting video prior to and following instruction is not surprising to us. We explicitly asked teachers to consider the task of capturing and selecting video prior to instruction, and, following instruction, we expected teachers to engage in review of video in order to select the precise clips to share with colleagues. However, we did not anticipate that teachers would engage in work around selecting and capturing clips *during* instruction to the extent that they did. Of course, some teachers were asked to mark moments of video during instruction, but the extent to which teachers from all three groups had a heightened awareness of what was taking place in their class during instruction was not something we anticipated. Furthermore, prior to this study, we were not aware of the specific ways that teachers engaged in capturing and selecting video and that different strategies were tied to specific time periods of use. Thus, the particular strategies that we present here are a primary contribution of this study. Moreover, we claim that each strategy represents an opportunity for teacher learning—for teachers to think about the act of teaching and learning in new ways. In what follows we describe each strategy in more detail and provide illustrative examples from the data.

Phase 1: prior to instruction

Much has been written about the work that teachers do in order to prepare for teaching (Clark and Peterson 1986; Yinger 1979). One line of research describes the cognitive processes that teachers engage in during lesson planning. For example, John (2006) describes lesson planning as a sort of thought experiment where teachers mentally run through key components of a lesson in order to prepare. Similarly, Morine-Dershimer (1978–1979) describes the development of a "lesson image" that provides a teacher with a high-level agenda for an upcoming lesson and in particular, structures the teachers' action during the lesson.

Another line of research around lesson planning looks at how teachers modify written curriculum materials in order to prepare for instruction (Remillard 2005). Such work emphasizes that no lesson is implemented precisely as written and that a lesson is always adapted to some degree. Sherin and Drake (2009) identified different ways that teachers engage in this work prior to instruction and highlight that for many teachers this involves making decisions about which lesson activities to include or exclude, as well as materials or activities that need to be modified or inserted for their particular context. Some teachers engage in this work with a primary focus on themselves as the key actor in the classroom while others focus more on the needs of their students (Drake and Sherin 2008). In related work, Smith and Stein (2011) describe the essential work of predicting student solution approaches prior to instruction, in order to prepare oneself to effectively monitor and support students' work during instruction.

Anticipate student thinking

In our work with teachers, we found that asking teachers to capture moments of student mathematical thinking during instruction prompted teachers to engage in a mental review of an upcoming lesson (or unit), similar to what has been described in the research on lesson planning. One teacher described it this way as he planned a lesson on synthetic division:

> My thinking was when I do this [activity], the students are going to do it, and then they're going to look at their partner's answers, and, you know, kind of see something, and like, it would be like, "Oh, like, why are these the same?" and like, you know, kind of generate conversation.

The focus of the mental review, however, seemed to be quite different. First, the subject was primarily the students rather than the teacher. Second, rather than predict student responses or strategies, teachers considered where and when they would best have access to students' thinking, that is where they would be able to catch students in the act of "doing math." For some teachers, this involved identifying which component of a lesson had the highest degree of student engagement around mathematics. For example, Stuart stated that he planned to record student presentations in an upcoming lesson on exponents because they "[make] student thinking visible" while Carly suggested that the time "when the class discussion happens" would be when she could "get students' thoughts [about cosines]." In other cases, teachers talked more specifically about a particular lesson component and mathematical content that they expect to engender students' thinking, such as when Leah stated "I'm planning to take the part of the lesson where students are first exposed to a rational equation and …challenged to use knowledge from earlier in the year to solve a problem. I think this piece of the lesson offers a nice chance for students to …demonstrate thinking." Similarly Mark explained that this "lesson is on writing an equation of a polynomial given a graph of the polynomial…The part of the lesson I'm interested in is…after…I put up a sketch of a graph and have students brainstorm…from [there]." As seen here, teachers at times pointed to specific points in a lesson as important to consider and described those specific points in the lesson in terms of the mathematics content and the student thinking involved.

In most cases, teachers seemed to equate student talk about mathematics with evidence of student mathematical thinking. However, in some cases, considering where they would find student mathematical thinking in a lesson also prompted teachers to think deeply about what it looks like to "see" student mathematical thinking, and the kinds of student thinking that students might exhibit in different activities. In particular, teachers at Baxter High School discussed the difference in the student mathematical thinking portrayed when students present a worked-out solution to the whole class "You get… highlights into… [the thinking] of anyone who's willing to share" versus seeing students solve a problem for the first time "[where you get to see them] really struggle and persevere and problem solve and try and try again…all of the messy grit."

We believe that these examples highlight teachers engaged in thinking about instruction in ways that are not typical of teacher planning. Specifically, asking teachers to locate where and when student thinking would be most visible in a lesson prompted them to think about the degree and depth of student thinking that would be revealed in class. Given the strong push for mathematics teachers to attend to student thinking during instruction, we think this is essential work. Teachers must have sufficient access to student thinking during class in order to support student learning (Franke et al. 2007). Additionally, we see evidence that teachers are being specific with reference to the mathematical content in this strategy. As a result, we find that teachers are not only thinking about when "math" happens, but what specific mathematics happens at those times.

Prepare to notice student mathematical thinking

With the previous strategy, teachers considered lessons yet to be implemented in order to decide where they would be most likely to see student thinking. In addition, we found that teachers engaged in an activity that we refer to as "preparing to notice." In the activity *anticipating student thinking,* teachers are considering where and when, broadly speaking, they are likely to observe episodes of student thinking worth capturing. In contrast, in *preparing to notice*, they are trying to construct, in their mind's eye, a sense of what it will look like.

Mason (2002) suggests that noticing is a discipline and that we can use "prospective imaging" to develop new ways to notice. Specifically, he finds that people can prepare themselves to be aware of specific kinds of events when they occur in the future (Mason 1998). We found that, in advance of recording, teachers engaged in just this kind of prospective imaging around student thinking. For example, Alex told us that in a lesson on rates of change he was going to be looking for "moments where students were figuring something out… where they going from being confused to understanding." Another teacher explained, "I'm looking for individual [student] comments … [where] I [say] 'Oh wow! That's a good insight…' or 'You completely missed [it].'" In these instances, the teachers have transformed the vague and general task of "looking for interesting student thinking," into a somewhat more specific task of looking for specific types of events.

A range of research demonstrates the consequential nature of teacher noticing. As Schoenfeld (2011) explains, teachers can only respond to what they are aware of during instruction. While we cannot be sure whether these teachers were preparing to notice student thinking in ways that they had not done previously, it seems quite possible that this was the case. Prior research documents that teachers often primarily attend to issues of management and behavior during instruction (Levin et al. 2009) and to a lesser degree to issues of student thinking. The fact that the teachers in this study are explicitly planning to look for student thinking in particular ways, we believe, has the potential to shift the nature of teacher's practice during instruction (Erickson 2011).

Phase 2: during instruction

Recent research characterizes teacher decision making as a dynamic process in which teachers work to coordinate myriad goals and actions. This complex decision-making process has been described by researchers in multiple ways. For example, Schoenfeld (2010) explains teacher decision making in terms of a model consisting of a complex network of *goals*, *resources*, and *orientations* that give rise to teachers' moment-by-moment decisions and corresponding actions. In this model, *goals* are conscious or unconscious objectives at multiple grain sizes. These goals are activated (and deactivated) throughout a lesson with different levels of priority. To realize these goals, teachers draw on *resources* that comprise a variety of types of knowledge. Furthermore, teachers' *orientations* concern teachers' attitudes toward teaching and learning as well as beliefs and values toward a subject matter. Orientations play a central role in how teachers' resources are applied and which goals are activated at any given moment.

Our point here is that the need to capture interesting episodes of student thinking must impact this already complex decision-making process. One way to see this is to note that, in terms of Schoenfeld's (2010) model, the need to capture episodes adds a new high-level goal to those that must be satisfied. It also likely impacts the teacher's orientations, since they may be more likely to be focused on attending to student thinking. More specifically, we saw two types of influences on teachers' in-the-moment thinking.

Focused noticing

During instruction, teachers attended to the task of capturing and selecting video excerpts of student mathematical thinking by engaging in what we refer to as *focused noticing*. Specifically, teachers explained that in the midst of instruction they found themselves noticing interesting moments of student mathematical thinking. Unlike the previous *preparing to notice* strategy where teachers identified a particular kind of student thinking prior to instruction that they wanted to be on the lookout for, here teachers described a heightened awareness of student mathematical thinking during instruction. Laura described it in the following way "…knowing I was trying to record student thinking made me more aware of whether it was happening." This took place in several different ways. For example, Courtney found herself attending to the range of methods students were using in a lesson on ratios, "I kept [seeing different] strategies they were using … for scale factor. One [strategy] relating back to the previous unit …. [and then] also …using division…in order to get that scale factor, and then [trying] different ways to set up [a ratio]." In other cases, unexpected student methods seemed to stand out to the teacher "I didn't expect anybody to know how to solve this algebraically" or the details of a student's approach "that was such an interesting way to find the slope field." Teachers also found themselves more aware at a general level of the extent to which student thinking was or was not visible in their classroom "There wasn't as much discussion as I had anticipated" remarked Alex, while Nora reflected "I was surprised by the amount of student thinking I heard."

Of course, our point is not that these teachers never previously attended to student thinking during instruction. Instead, our claim is that teachers seemed to be *more* conscious of attending to student thinking during instruction. Mason describes this as a*wareness of awareness* that teachers were both noticing and conscious of this noticing (Mason 1998). Thus, as teachers kept in mind the new goal of capturing student mathematical thinking, aspects of teacher noticing around student thinking that had been more tacit may have become somewhat more explicit.

Adjust instruction

A second strategy that we observed teacher using during instruction was to take some sort of action in order to make student thinking more visible during instruction. We refer to this strategy as "adjusting instruction." For example, one prospective teachers explained that she "tried to ask more open-ended questions" and "not give away the answer" to promote substantive student thinking in class. In other cases, teachers extended discussions in order prompt student thinking. As Kelly stated "I tried to [pause] a little more.. just to see … 'Is there anything interesting going to happen?' I'm going to give [the students] a little more of a chance to come up with something." And in still other times, teachers took very specific action in order to increase opportunities for students to engage with the mathematics. For example, Ray explains that he observed one student sharing an interesting method for solving quadratic equations with her group but the group members were not responding. "[I had] her restate it and [asked] other people … to identify what the variables were from that equation" in order to prompt a discussion among the group members. Thus, teachers seemed not only more aware of student thinking during instruction, but they also took explicit action in order to promote student thinking.

The adjustments to instruction that these teachers made are likely adjustments that we would *always* like them to make, not only when they are capturing videos, as they help students better share their thinking and provide teachers with additional access to students' ideas. Of course, we cannot be sure that these changes would lead to broader and more enduring changes to the practices of these teachers. But it is certainly plausible that they might. If so, this has the potential to both lead to an important shift in the nature of teachers' instruction (Levin et al. 2009) as well to increased opportunities for student learning (Franke et al. 2007).

Phase 3: after instruction

While reflection is generally considered a hallmark of effective teaching practice, there is not always consensus among researchers as to what this practice involves. As defined by Dewey (1933), reflection involves systematic consideration of knowledge that is grounded in evidence and intended to inform future action. It is the systematicity and rigor of the thinking that distinguishes it from everyday thought (Rodgers 2002a, b). Schön (1983) looked in particular at the reflective practices of teachers and defined reflection-on-action as looking back on previous action. Along these lines, Davis (2006) characterizes *productive reflection* as reflection-on-action in which teachers move beyond descriptions of events toward interpretation and analysis of what took place. Doing so can be challenging however. Furthermore, Davis found that the reflections of novice teachers tend to focus on themselves rather than on students and that when students are considered, the reflections emphasize issues of student motivation and engagement, rather than students' substantive interactions with the content.

Reflective noticing

We identified teachers engaged in two types of reflective activities after videotaping was complete. The first is what we call *reflective noticing*. As opposed to *focused noticing* which took place in the moment of instruction, *reflective noticing* occurred after instruction and involved teachers recognizing that an event or interaction that was not videotaped would have been interesting to capture on video. For example, Matt had chosen to record the portion of class when students worked together in groups. After the lesson, he explained, "I tried taping the small group…[but]I found…[it was] in the full class that they really sort of have to explain their thinking." Similarly, Jordan explained that sometimes when students share an interesting method in a whole-class discussion, she wished she could have "retroactively filmed [that] group of students to see how they got to the conclusions they did [about the area of the figure]." In some cases, the moment of interest took place in a class that had not been videotaped at all. For example, Trey had just videotaped a lesson on exponential growth in his 6th period class, and in talking with the researcher after class commented "4th period…conversations would be good to look at…where students didn't think it through all the way." Here Trey recognized differences between student thinking across two of his classes and sensed that viewing excerpts from 4th period along with those from 6th period would have been useful.

To be clear, *reflective noticing* was generally not primed by watching any video of instruction. Instead, it is a response to classroom events that was triggered, at least in part, by recent recording activity. This leaves us with two important questions: (1) Does classroom recording lead, on its own, to increased reflection about classroom events? (2) Is this reflection somehow different in kind?

The first question will likely always be a difficult one to answer. It is certainly not altogether unusual for teachers to reflect about goings-on in their classrooms. Creating an exhaustive census of this reflection, and quantifying it, would be a difficult task.

But we think we can get more purchase on question (2). It is possible, we believe, that the activity of capturing recordings leads to reflection on classroom events that differs in kind. Note that, in this type of reflection, a teacher asks herself: "What might I have captured in this lesson?" We believe this type of question leads to a productive frame for reflection. Note, for example, it directs attention away from a critical perspective, or from problems that were encountered during instruction. In a critical perspective, the teacher might ask questions such as "What went wrong?" and "What isn't working?" and "What should I have done differently?", all of which identify events without making explicit deep interpretation or analysis characteristic of productive reflection. By contrast, in this new frame of reflective noticing, teachers' curiosity focuses on uncovering why events happened, which is more analytical (Dyer and Kaliski 2016).

Assess potential clips

The second strategy teachers engaged in after instruction involved *assessing potential clips*. Here, teachers responded to viewing clips that they had previously recorded. In some cases, viewing the video confirmed for teachers that an excerpt did in fact portray student thinking as intended. For example, after watching a recent clip, Stuart explained that he had successfully captured student thinking, "students weren't just [giving] 'fill-in-the-blank' answers, they were explaining their method and [talking] about how to approach the problem." In other cases, however, watching the video highlighted for teachers that the video did not capture student thinking as they had intended. Mark provided an example of this when he explained, "I definitely did not capture what I intended to…I really meant for there to be more student exploration and contribution to the discussion [of polynomial division]. It wasn't until I watched the video that I realized how little the students contributed, and how much of it was me." We also note that some comments illustrate that when watching the video, teachers compared the expectations they had developed prior to a lesson with what they saw on the video. In other cases, teachers compared the sense of student thinking they had during instruction with what they saw on video, as in the second example. In either case, their comments highlighted that watching potential clips prompted teachers to reassess the student thinking as they had understood it previously.

Teachers also reflected on and assessed clips in a manner that would be more typical of a video club context. For example, Quinn explains that during class he had "no idea what [the student] was saying" but after watching the video "I think I kind of understand what she was trying to say [about exponential functions]." In addition, teachers did suggest some changes they would make in their instruction, based upon what they noticed in the video. For example, after watching a video of a whole-class discussion Mark commented "I…need to let students talk more…I could have bounced [Anthony's] question back to the class…I'm doing too much of the talking [and] thinking."

But what we find interesting is that teachers, as discussed above, assessed videos in a manner that would not be typical of a video club. As in *reflective noticing,* considering "What did/Should I have captured?" provides a unique frame within which to reflect on classroom events.

Discussion

Recent advances in digital technology offer new approaches for videotaping classroom interactions. In particular, it has become more feasible for teachers to capture video from their own classes. As a result, we suspect that mathematics teacher education and professional development efforts will increasingly rely on teacher-captured video as the basis for teacher learning. Here, we presented examples from three groups of teachers to support a model of the clip capturing and selection process. In particular, the model emphasizes that teachers engage in this work at three time periods, prior to, during, and after instruction. Furthermore, we articulate key strategies that teachers use within each time period in order to advance the work of recording and selecting video excerpts.

Although our framework separates the three phases of the capturing process, we believe that it is important to consider all three phases together to examine the process through which capturing and selecting video supports teacher learning. In many ways, the predictions and heightened awareness found prior to capturing influence when and to what teachers attend during the lesson and when reviewing clips. In particular, we suspect that many of the reactions that teachers had to their videos would have been less salient if they had not first made predictions about where to capture video. We suspect that making predictions about where student thinking will take place and what it looks like primes teachers to later consider the accuracy of their predications. In this way, we believe the capturing process supports the iterative hypothesis generation and testing that is central to teacher learning (Dyer 2015; Hiebert et al. 2003, 2007).

To consider the potential for mathematics teacher learning in the capturing process, we believe that the design of the video capturing task and prompt is central. Asking teachers to capture video related to student mathematical thinking seemed to be enough structure so that the task was accessible to both in-service and prospective teachers. At the same time though, it presented several questions that teachers had to consider including: What does student mathematical thinking look like? When is student mathematical thinking most visible in my classroom? How aware am I of the degree of student mathematical thinking taking place during instruction? Each of these questions raises issues related to the mathematics content as well as students. We suggest that struggling with these questions, and adapting how one engages with video as a result, represent important learning opportunities for teachers. While it was beyond the scope of the current paper to investigate the influence such work had on teachers' subsequent instruction, we think this is an important direction for future research. In particular, literature focused on teacher professional development has shown that this focus on student mathematical thinking can lead to improvements in teaching (Borko et al. 2015; Sherin and van Es 2009; van Es and Sherin 2010).

Furthermore, to be clear, we believe this focus on student mathematical thinking likely influenced the specific types of strategies that teachers used. If, for example, we had asked teachers to capture clips of whole-class discussion, some of the strategies might have been less relevant (e.g., anticipating), or teachers may have employed different strategies that were not identified in this study. As a result, we suggest that the strategies identified in this study are particularly relevant in the context of capturing student mathematical thinking. Furthermore, these strategies reflect portions of teaching that are rich in mathematics content, thus relating students and mathematics in potentially powerful ways (Lampert 2001).

Before concluding, we wish to raise two issues. First, technology certainly played a key role in how teachers engaged in the task of capturing and selecting video excerpts from their classrooms. To be sure, the fact that we explicitly encouraged teachers to record only a portion of a lesson certainly prompted them to try to anticipate where student thinking would be most visible in a lesson. Similarly, wearing a camera during instruction, and marking the video while teaching, certainly heightened the potential for focused noticing around student mathematical thinking. At the same time however, the fact that teachers from all three communities engaged in all three tasks suggests to us that the technology itself was not the defining factor and that instead it was the more general task of locating video clips of student thinking to share with peers that promoted the model that we present here.

Finally, we want to consider how to support and design teacher learning through the varied strategies presented here. For example, we have wondered if slight variations in the prompt as to the kind of video excerpt to collect might shift teachers thinking and activity in certain ways. Toward that end, we have experimented with asking teachers using the wearable camera to capture important moments rather than interesting moments. Preliminary analysis suggests that this difference in terminology did not result in significant differences in the kinds of clips captured. Similarly, we have explored different tasks for prospective teachers, including collecting video of "substantive student thinking" versus "student mathematical reasoning" versus "clips that would prompt discussions of student thinking among teachers." In this case, preliminary analysis suggests that the specifics of the prompt do result in different degrees of engagement with student mathematical thinking on the part of the teachers. This is an issue that we will continue to explore.

We believe this research has both theoretical and practical implications. It suggests to us new ways of understanding the nature of teacher cognition around the work of capturing and selecting video excerpts. And at the same time, it provides practice advice for those moving forward with professional development programs that provide opportunities for teacher-captured video to play a central role.

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