Research/Empirical

Preservice Teachers' Professional Noticing When Viewing Standard and 360 Video

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Abstract
Use of video as a representation of practice in teacher education is commonplace. The current study explored the use of a new format (360 video) in the context of preservice teachers' professional noticing. Findings suggest that preservice teachers viewing 360 videos attended to more student actions than their peers viewing standard video. In addition, using a virtual reality headset to view the 360 videos led to different patterns in where preservice teachers looked in the recorded classroom, and to increased specificity of mathematics content from the scenario. Thus, findings and results support the use of 360 video in teacher education to facilitate teacher noticing. However, future research is needed to further explore this novel technology.

Keywords
elementary teacher education, mathematics education, mixed methods, preservice teacher education, technology

Use of video in preservice teacher (PST) education is commonplace (Borko et al., 2008; Grossman et al., 2009). Incorporating video of teaching and learning has demonstrated positive effects on PSTs' professional noticing (Jacobs et al., 2010; Levin et al., 2009; van Es & Sherin, 2002) and their pedagogical content knowledge (Ball et al., 2008; Roth et al., 2011). Despite such demonstrated effectiveness, many PSTs continue to attend to less relevant aspects in such scenarios, without specific attention to important elements of content or pedagogy (Gaudin & Chaliès, 2015; Rosaen et al., 2008; Stockero et al., 2017; Talanquer et al., 2013; van Es & Sherin, 2002). Such evidence supports the call to improve the specificity of what PSTs attend to in viewing teaching scenarios.

A fundamental premise for using video in teacher education is that it provides "novices with opportunities to develop ways of seeing and understanding professional practice" (Grossman et al., 2009, p. 2065), particularly regarding specific aspects of practice. Scholars have attempted to improve representations by incorporating animations or comics (Friesen & Kuntze, 2018; Herbst et al., 2013; Moreno & Ortegano-Layne, 2008), using wearable cameras (Sherin et al., 2008), tracking instructors with a camera (Osawa & Asai, 2005), watching video of one's own teaching (Seidel et al., 2011), or using multiple cameras (Jackson & Cho, 2018). Such attempts to improve the authenticity of representations of practice tend to focus on what is perceivable in a representation (Herbst et al., 2013; Jackson & Cho, 2018); a construct defined in this article as a representation's *perceptual capacity* (Ferdig & Kosko, 2020; Kosko et al., 2019).

This article reports on the application of a new technology (360 video) to represent professional practice. The *360 video* format differs from traditional video in that it records a spherical view of a scenario. Using either a flat screen or virtual reality (VR) headset, a PST can adjust the field-of-view by moving the screen with a mouse/finger-tap or turning their head in a headset. The few identified studies examining 360 video use in teacher education have found PSTs report a higher sense of immersion and presence (Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019). An ensuing question is whether a higher sense of immersion translates into improved situational awareness, which, in turn, could signify higher precision in PSTs' professional noticing. The purpose of this study is to examine whether and how the use of 360 video affects PSTs' professional noticing for elementary mathematics.

Relevant Literature and Theoretical Framework

Understanding the professionalized knowledge and skill set of teachers has been a focus of researchers as early as the 1970s (Borko et al., 2008). There are various, often

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complementary models for explaining such constructs (e.g., Ball et al., 2008; Gess-Newsome et al., 2019), but this study focuses specifically on PSTs' attending within the construct of professional noticing (Levin et al., 2009; van Es & Sherin, 2002). Teachers' professional noticing is a form of situation awareness. As defined by Endsley (2000), *situation awareness* involves understanding what is occurring in a given scenario, while also understanding what is significant in such scenarios. First, individuals must possess a basic ability to attend to important aspects of a scenario. The second stage involves not only moving beyond simply attending to important information "but also the integration of multiple pieces of information and a determination of their relevance to the person's goals" (Endsley, 2000, pp. 3–4). The third stage involves projecting from a scenario to anticipate what happens next. These stages correspond with various frameworks for teacher noticing across content domains (Jackson & Cho, 2018; Rosaen et al., 2008; Talanquer et al., 2013). For example, Jacobs et al.'s (2010) construct for professional noticing of children's mathematical thinking includes attending to children's strategies, interpreting children's understandings, and deciding how to respond. The connection between situation awareness and teacher noticing has previously been noted (Amador, 2016), with the current study considering teacher noticing as a context-specific form of situation awareness.

The notion of attention or "attending to" is perhaps the most basic aspect of professional noticing. This fundamental characteristic of professional noticing has led to substantial research on *what* teachers attend to or notice. Using eye-tracking technology to compare experienced and novice secondary teachers' noticing, van den Bogert et al. (2014) found that experienced teachers process visual events in a recorded classroom more quickly, whereas PSTs tend to scan the room more frequently, with fewer fixations on particular students or events. This results in more specificity in description by experienced teachers. Such eye-tracking research corresponds with other literature on teacher noticing across multiple content areas including, but not limited to, mathematics education (Huang & Li, 2012; Jacobs et al., 2010), science education (Barnhart & van Es, 2015), literacy education (Beach et al., 2019), or study of general educators (Krull et al., 2007; Ross & Gibson, 2010).

Considering the differences in specificity of noticing between experienced inservice teachers and less experienced PSTs, it is important to note that "whether and how teachers [notice] largely reflects how they frame what is taking place in their classrooms" (Levin et al., 2009, p. 143). Specifically, the manner that a teacher, novice or experienced, engages in professional noticing can be influenced by factors like teacher knowledge and institutional constraints of their school or district (Herbst et al., 2016; Levin et al., 2009). Although PSTs tend to notice student actions and moments of content-specific significance with less frequency or specificity than experienced teachers, they can and often do notice such things. What is of interest to the present study is whether a PST's noticing habits can be improved upon in teacher training, and research comparing experienced and novice teachers can provide some insights into this phenomenon.

Comparing nine experienced and nine novice science teachers in Germany, Plöger et al. (2019) found that the experienced teachers both attended to a wider variety of effective teaching practices and did so more often. Examining a sample of 20 experienced and 19 novice Dutch teachers, Wolff et al. (2015) confirmed much of what prior literature suggests. Observed PSTs focused more on student behavior and classroom management, whereas expert teachers provided more substantial attention to particular content and related students' reasoning and teaching practice.

It is expected that PSTs would be less adept at professional noticing than experienced teachers. However, "expertise in attending to [students'] strategies is neither something adults routinely know how to do nor is it expertise that teachers generally develop solely from many years of teaching" (Jacobs et al., 2010, p. 185). The value of the literature comparing both populations is the nature of such differences and the prevalence of imprecise, less specific professional noticings of novice teachers (PSTs) regardless of their time spent in a teacher education program. Focusing on science education, Barnhart and van Es (2015) found that teachers may initially not notice student actions, but once they do, may focus on procedural aspects of the content. A more advanced form of attending was evidenced by describing conceptual aspects of the content as it relates to students' reasoning. A similar developmental trend has emerged in teacher noticing literature in mathematics education (Huang & Li, 2012; Jacobs et al., 2010) and literacy education (Ross & Gibson, 2010). Comparing expert K–12 literacy teachers with those teachers with less expertise, Ross and Gibson (2010) noted that the latter group's "noticing evidenced a lesser degree of elaboration across a narrower range of literacy behaviors" (p. 185). Thus, there appears to be a correlation between the depth of description, the number of specific student actions noticed, and demonstrated pedagogical content knowledge through integration of described students' actions and content-specific concepts. In the next section, we consider what efforts have been made to improve the specificity of what PSTs notice and thereby facilitate teachers' developed noticing.

PSTs' Attending Within Varying Representations of Practice

Efforts to improve the specificity of teachers' attending often adopt Grossman et al.'s (2009) pedagogies of practice: representation, decomposition, and approximation of practice. A *representation of practice* provides PSTs with opportunities to view teaching or evidence of student reason. A *decomposition of practice* engages PSTs in dissecting and analyzing components of teaching. Examples include online or face-to-face discussions of specific videos (Roth et al., 2011), as well as annotation technology that allows for the "marking and commenting on" (Herbst et al., 2016, p. 80) representations of practice in an interactive manner. An *approximation of practice* allows PSTs to enact some form of practice in a way that approximates teaching their primary audience, without necessarily engaging them. Variations include rehearsals of teaching (Benedict-Chambers, 2016), written or spoken descriptions (Walshe & Driver, 2019), and animated representations depicting what happens next (Herbst et al., 2016). Although both decompositions and approximations of practice are critical means of improving what PSTs attend to when learning to notice, a primary purpose of this study is to examine how variation in the representation of practice may affect PSTs' attending. Thus, the remainder of the article focuses predominately on representations of practice.

Grossman et al. (2009) suggested that representations come in many forms, including written narratives (e.g., classroom vignettes), artifacts from practice (e.g., examples of student work), and videos of classroom practice. The affordance of video providing a visual representation of classroom practice has been explored through several variations of this medium. Seidel et al. (2011) compared teachers' noticing when watching the video of one's own science teaching versus that of another's teaching. Interestingly, "teachers in the 'own' condition commented less critically and identified fewer consequences and alternatives" (p. 266) than comparison teachers. Sherin et al. (2008) piloted the use of a wearable camera that allows "one to capture the previous 30 seconds" (p. 31) of classroom instruction by pushing a button. Following three lessons where the teacher wore and used the camera, Sherin et al. (2008) reviewed the selected clips with the teacher and recorded his reflective reasoning for why he signified each moment as important. Comparing PSTs' interactions with written, video, and animated representations, different scholars have found that PSTs respond similarly to each medium and provide similar degrees of specificity toward the content (Friesen & Kuntze, 2018; Herbst et al., 2013; Moreno & Ortegano-Layne, 2008).

Efforts to study variations in representations of practice have included attention to the degree that individuals relate to, or are otherwise immersed in, the video presented. Although the video of one's own teaching may lead to a higher sense of immersion and more content-specific events noticed, this does not necessarily lead to critical reasoning about such noticed events (Seidel et al., 2011). Similarly, animations have elicited both a higher (Friesen & Kuntze, 2018) and lower (Herbst et al., 2013) sense of immersion than video, but in neither scenario were significant differences in the specificity of noticing observed. We believe a primary reason for this is that the various representations described here have similar degrees of perceptual capacity. Specifically, each aforementioned representation provides a limited visual of what occurs in a classroom. We articulate this distinction in the following section.

Perceptual and Embodied Aspects of Teacher Noticing

The usefulness of video in professional training stems from its capacity to present a viable representation of teaching and learning (Grossman et al., 2009). According to Herbst et al. (2016), such representations may be defined by their origin "from found to transformed to designed" (p. 82), the manner in which temporality is conveyed, and the extent to which a "representation captures the uniqueness of settings and participants" (p. 82). Although useful, Herbst et al.'s (2016) dimensions do not adequately differentiate between standard and 360 video of the same classroom lesson. Therefore, we utilized two terms to distinguish between standard or 360 video and the manner that PSTs and other teachers may interact with them: perceptual capacity and embodied interaction. *Perceptual capacity* refers to a medium's capacity for aspects of the scenario to be perceivable, including but not limited to what is potentially viewable (Ferdig & Kosko, 2020; Kosko et al., 2019). We use perceptual capacity to reference a spatial sense of a context, but it may be extended to other sensorimotor aspects to record perceived information (e.g., smell and feel). The limited literature on using 360 videos in teacher education suggests that PSTs appreciate the autonomy of changing the perspective of the camera. For example, Roche and Gal-Petitfaux's (2017) physical education PST participants noted that they "had the possibility to explore the whole situation and understand all the different aspects of the situation" (p. 3423). Walshe and Driver (2019) noted a similar observation of primary grade PSTs who used 360 cameras to record videos of microteaching. In each case, the perceptual capacity of 360 video allowed for PSTs to choose where they looked, a feature of 360 video that allows for more embodied interaction with the medium.

Scholars studying virtual environments use the term *embodied interaction* to describe approaches that cue the body "to enact certain actions and create physical representations that facilitate conceptual understanding" (Lindgren et al., 2016, p. 174). Thus, embodied interaction refers to how meaning is created through action, either through conscious or unconscious movements (Dourish, 2001), or other perceptual cues. In this study, a video (standard or 360) facilitates development of PSTs' reasoning through professional noticing. For both standard and 360 video, we believe that embodied interaction occurs, but 360 video encompasses more perceptual capacity. We hypothesize that this greater perceptual capacity better approximates if the PST was in the recorded classroom. When 360 videos are watched on a flat screen, we conjecture the ability to choose where the camera is pointing mimics an individual's choice to move their head.

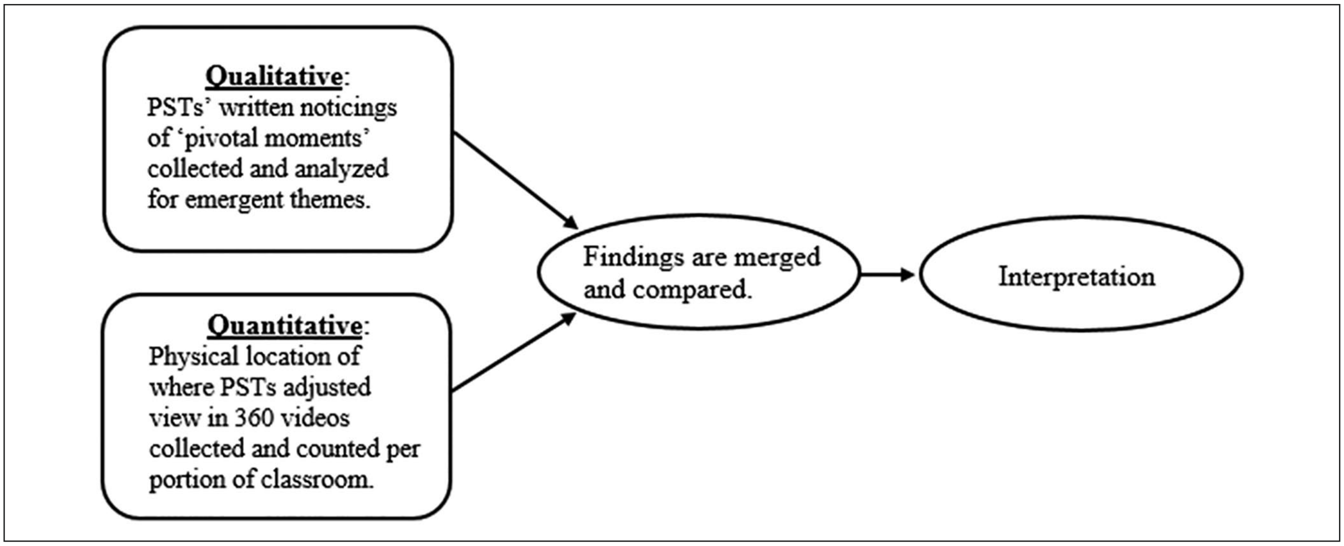


Figure 1. Overview of the mixed-methods design.
Note. PST = preservice teacher.

However, use of a VR headset to watch the 360 video likely mimics this choice of movement more closely.

Literature Review Summary and Research Questions

At the time of this writing, we have been able to locate only isolated examples studying use of 360 videos in the context of teacher noticing (Roche & Gal-Petitfaux 2017; Walshe & Driver, 2019). We conjecture that 360 videos have a higher degree of perceptual capacity, and viewing 360 videos with headsets may better support PSTs' embodied interaction to develop professional knowledge and habits. Furthermore, we hypothesize that both a higher degree of perceptual capacity and increased opportunities for embodied interaction facilitate more specificity in PSTs' noticing. This conjecture is based on the notion that 360 video represents embodied practice more closely than standard video. Thus, the purpose of this study is to examine the specificity of pedagogy and content noticed by PSTs in the context of perceptual capacity and embodied interaction. The study seeks to answer the following research questions:

> **Research Question 1:** How do PSTs' articulated noticings differ when viewing a standard video, 360 video on a laptop, or 360 video with a VR headset?
> **Research Question 2:** Is there a difference where (spatially) PSTs attend when viewing a 360 video on a laptop versus with a VR headset?

The first research question seeks to examine whether increased perceptual capacity interacts with the specificity PSTs attend to mathematics in a classroom scenario. The second question focuses on the potential effects of embodied interaction.

Method

This study incorporated a convergent mixed-methods approach in which qualitative and quantitative data were collected within the same phase of study, analyzed separately, and then merged for interpretation (Creswell & Plano Clark, 2018). As indicated in Figure 1, participants provided written accounts of what they noticed when viewing each representation of practice, and this was analyzed qualitatively using constant comparative analysis (CCA; Fram, 2013). In addition, participants' initial viewing of the 360 videos (either on a laptop or with a headset) were recorded as count data, signifying the number of 15-s intervals they focused on sections of the classroom. These count data were analyzed using nonparametric statistics (Siegel & Castellan, 1988). Both qualitative and quantitative data were merged to look for patterns across data types. Given the nature of convergent mixed-methods designs, both qualitative and quantitative data received equal prioritization. In the following sections, we explain the details of the participants, procedures for data collection, the representations of focus, and the analytical approaches employed.

Scenario and Representations of Practice Used

Three videos were created to represent the same 6-min, 58-s portion of a third-grade activity that informally introduced the Commutative Property of Multiplication. The class had 13 students seated at four tables. Students were provided a 7×8 array of 1 cm dots and sets of Cuisenaire rods. Cuisenaire rods include 10 different color-coded centimeter-based lengths (see Figure 2). Just prior to the recorded scenario, students had completed an introductory activity with the rods in which they covered a 4×3 array with one color rod. At the beginning of the video, students were asked to cover

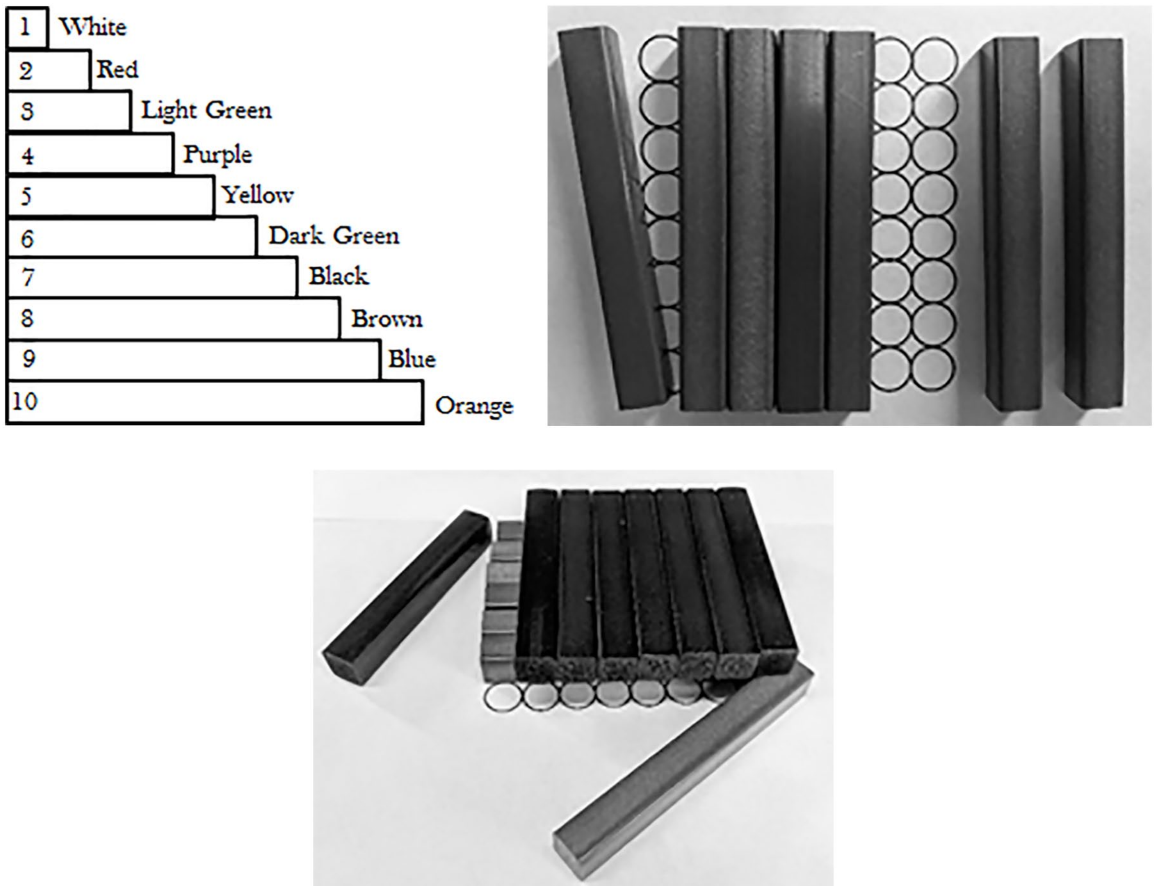


Figure 2. Cuisenaire rods and related task for representing $7 \times 8 = 8 \times 7$.
Note. The top-right image shows seven brown rods being placed atop the 8×7 array. The bottom-right image shows eight black rods being placed atop seven brown rods to informally illustrate $7 \times 8 = 8 \times 7$.

the new array (7×8) with only one color rod, so that the same rod-lengths covered all the array precisely. Over the next 2 min of exploration, several strategies can be observed, including using seven brown rods (8 cm), eight black rods (7 cm), 28 red rods (2 cm), and 14 purple rods (4 cm). Some students can be observed to initially try rod-lengths that do not work and quickly look for alternatives. Some students tried more than one set of rods, whereas others began to play with the rods after finding a working strategy.

After 2 min of exploration, the teacher asked students to share different combinations they used. Two strategies were shared with the whole class: eight rods of seven (black) and seven rods of eight (brown). The teacher noted that at least one person at each table used one or both of these strategies and acknowledged that many other strategies were used that were appropriate. Focusing on these two strategies, the teacher asked students to determine whether eight rods of seven would fit on seven rods of eight, or vice versa. Initially, half the class said no. The teacher pressed students to experiment with the rods directly. After a couple minutes of experimentation, the teacher asked the whole class what they noticed. This time, the entire class agreed that each set of rods fits on the other. The teacher asked students why the rods fit and received several responses. One student at a back table said you had to turn the rods and another student at a back table followed this comment by stating it was because the array was "seven down and eight across." After the teacher pressed students for more detail, two students at a front table talked about how the rod values and number of rods could be interchanged. Another student at a back table then commented that they were both 7×8 or 8×7. The last student comment focused on another strategy of using 28 rods of two. The video was edited to end at this point to allow for speculation as to what could or should happen next in the discussion.

The scenario described in the preceding paragraph was recorded using two 360 cameras: one positioned toward the front-middle of the classroom and the other toward the back-right of the classroom (see Figure 3). As previously described, 360 cameras record in a spherical direction. However, the video from a 360 camera can be edited to select one portion of that spherical image to create a standard video. This

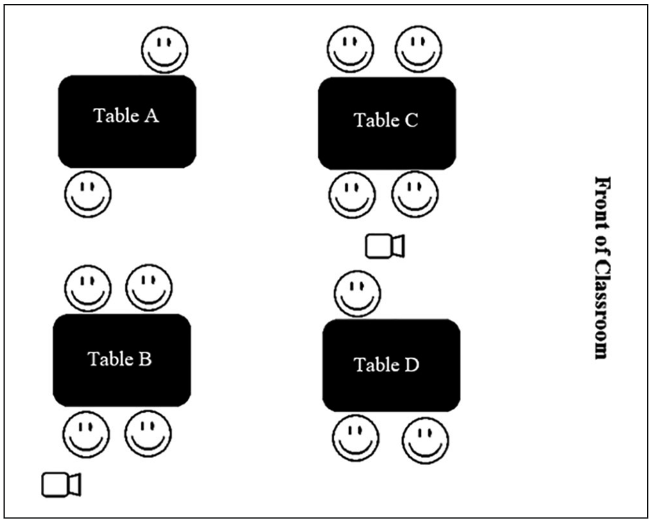


Figure 3. Layout of the classroom with illustrated position of 360 cameras.

allowed for the creation of a standard video for comparison with a 360 video but introduced a pragmatic challenge of which cameras to use for each video. Specifically, creating a standard view video with the camera at the front of the classroom would allow for, at most, half the classroom to be viewable. It also introduced the complication of determining where the camera was pointed. However, using the 360 video from the back corner of the classroom does not visually add anything to what a standard view video would, as rotating the video beyond its initial frame would only allow the viewer to see two walls of the classroom.

The decision was made to use the back-corner camera to create the standard view video and the front-center camera for the 360 videos (see Figure 4). This best approximates how a stationary standard video camera (Fadde & Zhou, 2014) and stationary 360 camera would most likely be used to record classroom practice (see examples from Kosko et al., 2019; Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019). We acknowledge that having the standard and 360 cameras do alter what is viewable to some degree. In the recorded scenario, a student at Table B uses 16 rods of four as an initial strategy, and this was not used at either Tables C or D. Also, the 28 rods of two strategy shared with the class was used by a student at Table D. Regardless of camera location choice, we conjecture that any use of standard or 360 cameras in a whole class context is likely an apples-to-oranges comparison. Fundamentally, they are different mediums for representing practice. However, we contend it is a comparison worth making to better understand affordances and constraints of each. The current study focuses on one context for comparison, acknowledging that other comparisons of camera placement and filming context may yield different results.

The standard view video was made available to participants to view on a laptop computer and the 360 video was made available to view in two ways: on a laptop computer and with an Oculus Go VR headset. We believe that the three representations of practice convey the same degree of cadence of events as well as representing the same or similar events of students' reasoning, but vary in regard to the perceptual capacity conveyed (standard video vs. 360 video) and the embodied interaction that may occur (360 laptop vs. 360 headset).[1]

Participants

Participants included 33 PSTs (one male and 32 females) enrolled in an early childhood education program (pre-K–3) at a Midwestern U.S. institution. All participants were enrolled in the first semester of their senior year (preceding full-time student teaching) in the second of two mathematics methods courses. Whereas the first course focused on number sense, place value, and geometry, the second course focused more on multiplicative reasoning, fractions, and measurement. Thus, participants were enrolled in a course related to content within the video they watched. In addition, all students used National Council of Teachers of Mathematics's (NCTM, 2014) *Principles to Actions* as one of their assigned books for both courses. The book focuses on key reform-oriented pedagogy for mathematics instruction and is used regularly across their methods coursework.

Students were emailed to solicit their participation. Following recruitment, we used responses to the poll on availability to create a set of sessions, and then randomly assigned sessions to one of three conditions: the *standard laptop* condition ($n = 8$), the *360 laptop* condition ($n = 11$), and the *360 headset* condition ($n = 14$). Some participants rescheduled to a different session ($n = 5$) and one was unable to participate at the last minute. This explains the slight skew of sample size across conditions.

Procedure

PSTs who participated in this study ($n = 33$) completed a 30-min teacher noticing activity outside program and course requirements. Participants in each condition met in separate sessions but completed the same materials with differing viewing conditions. In each condition, the participants did the following:

- PSTs reviewed the 7×8 array task and predicted what they may notice in the video.
- After a first viewing of the video, PSTs listed what they noticed in the video.
- After a second viewing of the video, PSTs listed what they noticed in the video.
- PSTs reviewed their lists of what they noticed and selected two they considered most important and explained why they believed the two noticings were important.

Figure 4. Standard video (left) versus a stretched 360 video view (right).

Prior to viewing the video, PSTs were presented with a synopsis of the task that students in the video completed. Participants were provided an opportunity to use Cuisenaire rods to experiment with the task. After the participating PSTs were provided time to become familiar with the task (~5 min), they were asked to predict what pivotal moments (moments of interest for the teaching or learning of mathematics) they expected to see in the video. Participants typed all responses in an electronic document. Participants then viewed the video and were asked to type all pivotal moments they had noticed in their initial viewing. Participants watched the video a second time and revised or added to their previous list in a new prompt. PSTs were then instructed to select two pivotal moments they believed were the "most informative for (them) as a future elementary math teacher," to describe the most salient part of each pivotal moment, and to share why they selected each pivotal moment. Participants concluded by completing a brief follow-up survey that assessed their perceived immersion and presence. Findings from the survey are presented in Ferdig and Kosko (2020), with the present study focusing specifically on data collected from PSTs' typed descriptions.

In addition to the data collected from PSTs' written noticing, participants' screen views in both the 360 laptop and 360 headset conditions were recorded to account for potential variation in how the perspectives were adjusted. Specifically, as 360 video allows the viewer to choose where to position the video view, we recorded this interaction to study where PSTs chose to position the camera perspective when watching the video on their first viewing.[2]

Analytic Approach

Qualitative Analysis

CCA was incorporated to examine PSTs' written responses, with particular attention to PSTs' written noticings and accompanying rationales for these choices. As noted by Fram (2013), CCA "is an iterative and inductive process of reducing the data through constant recoding" (p. 3). Although initially ascribed as part of grounded theory (Charmaz, 2014), the approach has evolved into a method of its own (Fram, 2013). In the present study, we used elicited documents in the form of PSTs' written responses regarding pivotal moments they noticed or anticipated noticing (in the case of the prompt following familiarization with the task). An advantage and disadvantage of elicited texts is that they allow participants to provide as much or as little detail as they choose (Charmaz, 2014). We acknowledge that although there is value in data from such sources, caution should be taken in interpretation of findings.

Following guidelines from Charmaz (2014) and Fram (2013), the PSTs' written responses were coded. In the first rounds of coding, we focused on written responses following the second viewing of the scenario to create an initial set of codes. However, written responses for the other prompts were later included in the analysis. As is customary in such a process, initial codes were broad ranging and tended to incorporate actions as descriptors. Initial codes were then compared and discussed to create broader categories and preliminary definitions for those category codes, as well as example descriptions for confirmatory and disconfirmatory evidence toward them. Finally, we engaged in additional rounds of coding to solidify an understanding of the emergent themes. To accomplish this, PSTs' responses following task familiarization and first viewing of the scenario were used. As discussed in the findings, the process led to the incorporation of a variation of axial coding to articulate the dimensions of a particular category in the data (see Charmaz, 2014).

Quantitative Analysis

We used nonparametric statistics to examine trends in where PSTs looked when watching the 360 laptop and 360 headset scenarios. To create a quantitative data set representative of where PSTs attended, we created a simple coding protocol. First, the perceptual field of view was partitioned into five parts, as considered from the perspective of the 360 camera used. These five partitions were centered on where students were concentrated and where the recorded teacher was active (see Figure 5). A sixth partition (indeterminate) was included for intervals in which a partition of focus could not be identified. Each 6-min 58-s recording was

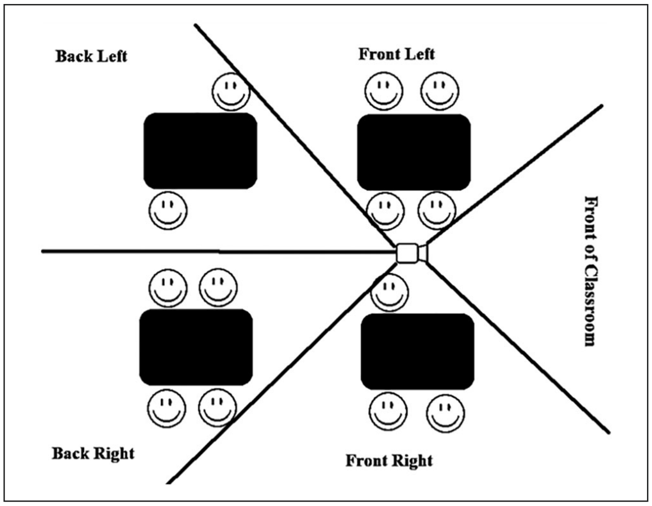


Figure 5. Divisions of perceptual field for coding of quantitative data.

coded in 15-s intervals (28 intervals per participant), with the last interval being only 13 s. Codings represent count data signifying whether a participant spent the majority of an interval viewing the scenario at a particular partition (back-left, front-left, front, back-right, front-right, or indeterminate). Three PSTs' recordings were not included for final data analysis due to errors in the recording process. In sum, 22 PSTs' recordings were coded, representing 616 intervals.

Findings and Results

Qualitative Findings

Two primary themes emerged from the qualitative analysis of PSTs' articulated noticings: *reform-oriented pedagogy* and *specificity of the Commutative Property*. For each theme, there were subtle but important differences in how they emerged in each viewing condition (standard, 360 laptop, or 360 headset). We articulate these differences in discussion of each theme below.

The first theme, reform-oriented pedagogy, refers to specified "pivotal moments" and any accompanying rationales that pointed toward pedagogical moves advocated by current mathematics education reform. Given that all participants were reading *Principles to Action* (NCTM, 2014) in their coursework, the text was referenced in considering their responses. For example, the text articulates productive pedagogy with teacher actions and student actions juxtaposed. One described student action for when the teacher is promoting problem-solving is that they are "persevering in exploring and reasoning through tasks" and "accepting and expecting that their classmates will use a variety of solution approaches . . ." (NCTM, 2014, p. 24). Notably, this is one reform-oriented practice consistently referenced across viewing conditions. We focus on this reform-oriented practice in the excerpts presented here for sake of comparison across conditions but note that it was not the only reform-oriented practice that was cited by participants.

Ariel, who watched the standard video, wrote the following after her first viewing of the activity:

> There was trial and error until the student found rods that would fit perfectly . . . one student tried having the rods going in different directions, one horizontal and the other vertical, while some chose to have all of their rods going in the same direction.

Ariel's focus on "trial and error" in this excerpt was expanded upon after watching the video a second time. Specifically, Ariel viewed children's actions here as ways to experiment and persevere in their problem-solving. However, in referencing the portion of the lesson when students placed one set of rods on another, Ariel noted that "children knew why it worked but couldn't/wouldn't explain why." Another participant who also watched the standard video, Asia, focused on the portion of the activity where students stacked the rods, but noticed different interactions regarding student explanation:

> The students were capable of explaining that they rotated the rods to get them to fit exactly. This is important because it shows that children are definitely capable of explaining their reasoning in math and this task shows value in talking about math.

Like Ariel and Asia, Buffy, who viewed the 360 video on a laptop, also noticed students' experimentation through their attempts to "figure out different techniques." A key difference in Buffy's description from either Ariel or Asia's are the examples Buffy provided of this discussion:

> I saw the children trying to figure out different techniques to get one rod the same color to fit. I also saw children talking to each other that they got different colors to work. When they were asked to fit them on top of each other, it came easily to some groups and harder for others. The explanations of why it could happen was very unique for each student in the class. They all had their own ideas why it would work.

Buffy included multiple references to group work, stating "I saw the children. . . I also saw children. . . it came easily to some groups and harder for others. . ." Buffy referenced more specific moments following her first and second viewings than either Ariel or Asia, but it was the relative consistency of these noticed moments that stood out, rather than the number of moments cited. Specifically, a large portion of Buffy's noticings included multiple examples of student actions for the same event (stacking the rods). PSTs in the standard video condition tended to articulate fewer examples of the same event than those watching the 360 videos (laptop or headset).[3] One potential explanation for this observation is due to the increased perceptual capacity of 360 video.

The second theme, specificity of the Commutative Property, emerged as separate actions that were eventually developed into an axial code: not conveyed, tacitly conveyed, implicitly conveyed, and explicitly conveyed. Ashley, who watched the standard video, exemplifies participants who were not observed to reference the Commutative Property.

> There's (sic) many ways of completing this task. Students, even after the teacher guided with the brown and black rods, went on to ask if there were other ways to solve this task. It's important for students to understand not everything in math is about being right or wrong and there are multiple solutions or answers to many math questions/many of life's questions really.

Ashley's reference to the brown and black rods suggests the possibility that she may have recognized the property. Whereas she referenced the rods themselves, she did not reference the relationship between the rods in any of her written responses. By contrast, Buffy's response below referenced stacking the rods and the moment of them "working together."

> Another pivotal moment I saw this time was all the children saying that they would not work on top of each other and then when working together they all said it did. Some groups didn't understand at first why it would be able to work but then understood that it was a multiplication problem.

We considered the distinction between simply referencing rods versus referencing relationships or interactions between them as a tacit noticing of commutativity. Roughly 24% of PSTs in our sample did not attend to the Commutative Property in their written noticings, whereas 36.4% did so tacitly.

PSTs who implicitly conveyed the property went beyond referencing a relationship between the rods by articulating the relationship numerically. Brandy, within the 360 laptop condition, referenced the stacking of the rods in her initial response to viewing the video before explicitly naming the relationship after the second video, as exemplified in her response below.

> The student pointing out that the numbers were the same, but just reversed, which is why the rods needed to go a different direction . . . it started the conversation about 8 times 7 being the same as 7 times 8, and provided another reason as to why this worked.

The linguistic turn of referencing numbers instead of colored rods was distinct and occurred in both the standard video and 360 laptop conditions (21.2% of overall participants). Interestingly, 15.2% of participants went beyond referencing the numeric relationship by referencing the mathematical property itself. Consider the excerpt from Chantel's written noticings after viewing the 360 video on the headset.

> The realization that 7×8 and 8×7 gives you the same answer—commutative property. I think this is important because understanding this property and illustrating it helps students understand why this property works.

Whereas Brandy stated that her attended moment was important because it helped show why $8 \times 7 = 7 \times 8$, Chantel referenced $8 \times 7 = 7 \times 8$ in the scenario as a way of helping students to understand the property, not the specific math equation. This is a key difference, mathematically, in being able to generalize beyond a specific case to a significant property in the discipline. Notably, explicitly referencing of the property was found only for participants in the 360 headset condition.

PSTs observed to either not convey or tacitly convey the Commutative Property were found across all three viewing types (see Table 1). Charlotte was the only participant in the 360 headset condition who did not reference the Commutative Property. Interestingly, her response differed from other PSTs who did not attend to commutativity as her response focused on multiplication, specifically the relationship between multiplication and division. Charlotte's written noticing seemed to be influenced by her prior professional experiences, a factor we did not explicitly examine in the present study.

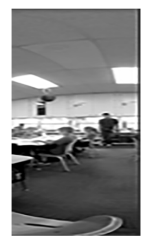
Another feature of how specificity of commutativity emerged within the 360 headset condition is how reform-oriented pedagogy also was evident in PSTs' writing. Candi's tacit attending to the property was frequently intertwined with references to the reform-oriented practice valuing different, but valid, mathematical approaches to solve a problem. In explicitly referencing the property, Coco relates children's interaction with it as also effective mathematical modeling "with a physical and visual representation." In a later prompt, Coco connects modeling the property to other reform-oriented practices of persevering in their problem-solving through argumentation, stating the task "gives students the skills to defend and change their thinking. If more open-ended opportunities like this were provided to students, then I think their problem-solving skills will be practiced in practical and hands-on ways."

In a similar manner, Chantel, another 360 headset participant who explicitly attended to the property, stated that "[students] changing their minds from black and brown NOT fitting together to realizing that they DO . . . is important because it shows students that math does not always work out correctly the first time. . ." and that this experimentation helped students to understand the property more thoroughly. Thus, the specification of the mathematical property interacted with how Coco and Chantel considered students engaged in the doing of mathematics. A similar interaction was observed for PSTs who attended to reform-oriented practices in the standard and 360 laptop viewing conditions. Even when PSTs tacitly referenced the commutative

Table 1. Example Excerpts of Participants' Specificity of Commutative Property.

Code	Percent attending By condition	Example
Not conveyed	24.2% overall *Standard* = 2 *360 laptop* = 5 *360 headset* = 1	Charlotte (360 headset view): "The students connected the activity to multiplication. It helps them to better understand multiplication, which then in turn would help them understand division. I chose this because I was in third grade last semester and noticed that a lot of them were struggling with these two concepts."
Tacitly conveyed	39.4% overall *Standard* = 2 *360 laptop* = 3 *360 headset* = 8	Candi (360 headset view): "The realization that the rods could be turned and still fit was one of the most important parts. This reinforces the fact that children think differently and see math differently are why this is so important."
Implicitly conveyed	21.2% overall *Standard* = 4 *360 laptop* = 3 *360 headset* = 0	Brandy (360 laptop view): "The student pointing out that the numbers were the same, but just reversed, which is why the rods needed to go a different direction . . . it started the conversation about 8 times 7 being the same as 7 times 8. . ."
Explicitly conveyed	15.2% overall *Standard* = 0 *360 laptop* = 0 *360 headset* = 5	Coco (360 headset view): "Students were building off of previous statements from each other before concluding that 7 × 8 = 8 × 7. A student stated, 'The numbers are on different sides, so you had to flip the rods around.' This is an effective understanding of the property and is paired with a physical and visual representation."

Table 2. PSTs' Emphasis of Attending to Certain Zones in the Classroom.

Condition	Back-left	Front-left	Front	Front-right	Back-right	n/a	Total
							
360 Laptop	10	114	41	59	28	28	280
	10.0	*103.6*	*55.9*	*68.6*	*16.8*	*25.0*	
360 Headset	11	114	82	92	9	27	336
	11.0	*114.4*	*61.7*	*75.7*	*18.6*	*27.6*	
Total	21	228	123	151	37	55	616

Note. Observed counts are in regular text and expected counts are in italicized text. In addition, the reference image is from a stretched image and appears as a distorted partition of the classroom. Figure 5 provides a more accurate representation of partitions. PST = preservice teacher.

property, there was an interaction, but the interaction between reform-oriented pedagogy and specificity of the Commutative Property appeared more cohesive as more references to reform-oriented actions were made and more specificity of the content was attended.

Quantitative Results

Quantitative analysis applies only to the two 360 viewing conditions (laptop and headset) as these were the only conditions we were capable of recording where PSTs oriented their view. Recall that the video was divided into 15-s intervals, with the interval serving as the unit of analysis. The 616 intervals across 22 participants were placed in a contingency table (see Table 2) and a chi-square statistic was calculated. Results suggest that the distribution of where PSTs looked, across the 360 video viewing conditions, was not independent from chance, $\chi^2(df = 5) = 25.959, p < .001$. In examining the observed and expected counts in Table 2, it appears that the placement of the 360 camera between the two tables in the front-left and front-right views increased the likelihood that PSTs looked in these portions of the perceptual field of view. In other words, PSTs attended to events closer to their perspective more often than they attended to events further away. Yet, there are noticeable differences across conditions.

There were two time frames of the recorded scenario where the differences in attended zone were most noticeable. First, there was a significant portion of time in which students were working in their small groups: finding single-color rod strategies to cover the array and later determining whether the black and brown rods would overlap exactly.

This portion of the scenario appears to explain a portion of the differences observed for the front-right zone ($Z_{headset}$ = 3.24) and the back-right zone (Z_{laptop} = 3.91, $Z_{headset}$ = −3.35). A large portion of the difference in observed and expected frequencies in the frontal zones come from the end of the recorded scenario. Here the instructor was in the front of the classroom facilitating a discussion with the students. During the discussion, two students in the front-right zone made comments related to the relationship between 8 × 7 and 7 × 8. However, the Commutative Property was never explicitly mentioned. Notably, PSTs in the 360 laptop condition attended to the front of the classroom less than expected by chance (Z_{laptop} = −3.16), whereas those in the 360 headset condition attended to this zone at a rate higher than expected by chance ($Z_{headset}$ = 4.30). In addition, there were a higher proportion of intervals coded for the front-right zone in the 360 headset condition during this time frame than in the 360 laptop condition.

The results suggest that PSTs using the headset were more likely to attend to the three portions of the classroom closest to the 360 camera than those using the laptop to view the same video. Given the context of when certain intervals were coded in the scenario, and the location of the camera (between the front two tables), the construct of perceptual capacity appears to have interacted with what PSTs were able to see. Notably, PSTs using the headset attended to the three front portions of the classroom in 85.7% of coded intervals, whereas PSTs using the laptop attended to these portions in 76.4% of coded intervals.

Merging of Data

As the quantitative analysis included only the 360 laptop and 360 headset conditions, the merging of qualitative findings and quantitative results is limited to only these conditions. Note that the first of the two emergent themes from the qualitative analysis observed that PSTs attended more examples of reform-oriented practice when watching 360 laptop and 360 headset videos, as opposed to standard video. Although an important observation, we were unable to merge findings from the quantitative data as we were unable to examine the facet of where PSTs attended in standard video. Thus, our focus on merging of data considers the latter of the two themes more heavily: specificity of the Commutative Property.

Qualitative findings revealed that PSTs in both the 360 laptop and headset conditions were observed to either not mention or tacitly convey the Commutative Property. However, divergence was observed between implicitly and explicitly conveying the property, as well as how PSTs integrated their noticings with reform-oriented practices. Quantitative results examining the frequency of intervals that PSTs attended to portions of the classroom provides some potential reasons for the divergence observed in the qualitative portion of the study. Specifically, PSTs in the 360 headset condition attended to all three frontal zones of the classroom, including the intervals in which the instructor facilitated a class discussion about the task, and students from the table in the front-right zone made specific comments about the relationship between 7 × 8 and 8 × 7. Thus, the role of PSTs' embodied interaction appeared to interact with the perceptual capacity of the available video. This suggests that allowing for more embodied interaction with the video, through the headset, may have encouraged PSTs to attend to students at both tables in the front of the room and the instructor during class discussion.

Discussion

Digital innovations continue to change opportunities for teaching and learning, including efforts to improve the authenticity of representations of practice (Herbst et al., 2013; Sherin et al., 2008). In this study, we examined whether and how 360 video technology affects PSTs' professional noticing in the context of an elementary mathematics lesson. Findings revealed that PSTs using 360 video attended to more student actions in their written noticings, with more descriptive references to such actions than PSTs who viewed a standard video of the same scenario. This occurred for both reform-oriented and content-specific noticings. In addition, when PSTs used a headset rather than a laptop to view the scenario, they attended to different areas of the recorded classroom, leading to increased specificity in descriptions of the mathematics at hand. Given that all participants in the present study are PSTs with the same relative professional experience, findings of the present study are highly significant. Specifically, there is extensive evidence suggesting that as teachers gain more experience, they attend to more student actions, write lengthier descriptions, and attend to more specific aspects of the pedagogical content in recorded scenarios (Barnhart & van Es, 2015; Huang & Li, 2012; Jacobs et al., 2010). The current study's findings seem to suggest that use of 360 video has the potential to significantly improve the quality of PSTs' professional noticing. Yet, there are relatively few analyses of teacher noticing in the context of 360 video (Walshe & Driver, 2019) and this study is the first to compare teachers' professional noticing across standard and 360 video viewing mediums. So, although we believe that the results provide important implications for teacher education, we also caution against making too bold of claims about use of 360 video in teacher education without additional, future research.

Prior research suggests that teachers with more experience notice more student actions with more sophisticated description of those actions (Barnhart & van Es, 2015; Huang & Li, 2012; Jacobs et al., 2010; Krull et al., 2007; Ross & Gibson, 2010). Although the magnitude of difference is smaller, we observed a similar distinction between PSTs who viewed standard video versus those who viewed 360 video.

Likewise, the difference in content-specificity of PSTs' noticings between the 360 laptop and 360 headset conditions resembled observed differences in teachers' noticings of procedural versus conceptual aspects of content (Barnhart & van Es, 2015; Ross & Gibson, 2010). One limitation of our exploratory study is that we were unable to collect significant data on PSTs' pedagogical knowledge at the beginning of each session. In addition, this study focused on a single 30-min session for PSTs toward the end of their undergraduate coursework. Although literature on how PSTs frame their noticing (Levin et al., 2009) and how professional noticing develops (Barnhart & van Es, 2015) inform both the implications and conclusions from this study, our findings and results speak more directly to the affordances that certain technologies may provide for facilitating professional noticing.

Limitations of the Current Study

There are several limitations of the present study. Although comparable to the sample sizes of many studies on teacher noticing, the sample size incorporated in the present study is limited. A larger sample would allow for certain statistical analyses on themes identified by the qualitative analysis, what Creswell and Plano Clark (2018) described as quantitization of data. In addition, the sample includes seniors enrolled in a single undergraduate teacher education program. It is possible that different patterns in teacher noticing may emerge depending on the context in which PSTs are educated and the stage they are within that program.

Given the exploratory nature of the present study, there are several factors and procedures that, provided the chance to conduct the study again, we would wish to incorporate. First, the size and scope of the current study did not allow us to formally assess participants' pedagogical content knowledge prior to their engagement in the teacher noticing activity. Second the findings suggest that PSTs viewing 360 video may have improved PSTs' professional noticing. It would be useful to compare professional noticing of more experienced teachers viewing the same scenario, within the same conditions. This would improve our understanding of the degree to which 360 video facilitates, and/or improves, teacher noticing.

Conclusion and Future Research

Findings presented here provide empirical support for the importance of PSTs' embodied interaction with their professional noticing when using 360 video headsets. These findings have important implications for research and practice. Prior research on teacher noticing has observed improved specificity in professional noticing when engaging PSTs in decomposing or approximating practice (Stockero et al., 2017), but not when simply responding to a representation of practice (Friesen & Kuntze, 2018; Herbst et al., 2013). As 360 video and VR headset technology become more commercially available, the ease of implementing them into teacher education will increase.

As technology evolves, both the perceptual capacity of 360 videos and the ability for facilitating PSTs' embodied interaction to develop their professional knowledge will also evolve. Related to such efforts is a need to study the pragmatics of implementing 360 and VR in research and practice. For example, findings presented here suggest that using an inexpensive VR headset can improve specificity of PSTs' attending. However, such headsets are currently bulky and usually must be used on campus. As technology evolves, the availability of lightweight hardware may improve, and this may, in turn, affect the manner and frequency they interact with it.

There are additional technological limitations as well as proposed innovation in 360 video that could drive future research. For instance, having multiple 360 cameras in a classroom would allow PSTs to virtually move about the room and could affect their perceived immersion. However, current technologies do not allow for free movement (e.g., getting nearer to a specific student). In addition, audio in many 360 cameras operates like standard video cameras, but newer microphones are now allowing for 360 capture of sound. As PSTs move their heads, they may focus on audio in different parts of the room. With time and innovation, these and other new innovations can be examined for their effect on noticing.

This study provides evidence of differentiation between headset and laptop users. However, further study is needed to understand whether this differentiation was simply a design issue (i.e., the technology made it difficult to look around in a laptop version) or whether the headset somehow encouraged viewing in certain regions, and why this led to more specific reference to the content. In addition, a difference between 360 laptop and 360 headset conditions was not observed regarding reform-oriented noticings. It is possible that a difference is present but not detectable with our sample. Thus, future study should not limit itself to differences in content-specificity alone. Furthermore, additional research should address the replication of these findings in contexts outside of mathematics education. There may be nuances in the way that 360 video is incorporated across various domains; future research within given content areas could explore such variation.

This study provides empirical evidence that using 360 video, instead of standard video, has the potential to improve the quality and depth of PSTs' professional noticing. Furthermore, using headsets may improve the specificity to which they attend to pedagogical concepts in recorded scenarios. These outcomes suggest that 360 video may hold promise for improving teacher education. It is, therefore, worthy of continued exploration and implementation. Yet, as articulated throughout this discussion, more research is needed to better understand how and when this medium can best be used in teacher education, and how teacher educators and educational researchers can develop and study best practices for this emerging technology.

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Notes

1. Readers interested in viewing these, and other, project-related videos on a flat screen or headset may visit the project website at https://xr.kent.edu
2. We attempted to record second viewings as well, but several participants using the Oculus Go did not set to record their second viewing and we, therefore, did not include this for analysis in the present article.
3. Although not the focus of this section, there is quantitative data to support this finding, as reflected in the average word counts for typed noticings (standard view = 274 words, 360 laptop = 291 words; 360 headset = 328 words).

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