



Using 360-degree video to explore teachers' professional noticing

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ABSTRACT

Professional noticing is an essential skill for teachers that is enacted by teachers via their embodied senses (sight, sound, etc.). To better understand the nature of teacher noticing, 44 preservice teachers (PSTs) viewed a 360 video of an elementary mathematics lesson while wearing virtual reality headsets. PSTs' writings of what they noticed and recordings of where they turned their head while wearing the headsets during the recorded scenario were examined. Findings suggest that how PSTs positioned students and the teacher in their field of view interacted with whether and how such events were described in writing.

Professional teacher noticing is a fundamental skill for educators that involves attending to key elements of pedagogy, interpreting those elements, and acting in accordance with that interpretation (Gaudin & Chaliès, 2015; Levin et al., 2009; van Es & Sherin, 2002). Over the past few decades, research focused on teacher noticing has focused primarily on use of video to investigate this construct. Video affords many advantages as a representation of practice, as it provides teachers an opportunity to “witness firsthand the application of pedagogical theory in a practical setting” (Brunvand & Fishman, 2007, p. 172), and can “communicate to viewers something of the chaos and complexity of classroom interactions” (Miller & Zhou, 2007, p. 332). Yet, for all its benefits, standard video is limited regarding how much it conveys of the “blooming, buzzing confusion” (Sherin & Star, 2011, p. 69) of sensory data that “bombards” a teacher. In a standard video, what a viewer is capable of attending is limited by what is selected, for them, on the screen. Within an actual classroom, a teacher must choose where and when to look, and what of the cacophony of student voices and actions they attend.

Until recently, more realistic representations of practice were either limited or unavailable. However, various forms of virtual reality (VR) have recently been incorporated into analyses of teacher noticing in various contexts including, but not limited to, 360-degree video (Ferdig & Kosko, 2020; Gold & Windscheid, 2020; Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019), non-interactive VR classrooms (Huang, Richter, et al., 2021), and interactive VR classrooms (Ke et al., 2020; Lamb & Etopio, 2020). Within teacher education, VR has been defined as “a digital re-presentation of an environment and can be animated ... or recorded” (Kosko, Ferdig, & Roche, 2021, p. 263), with the primary role of VR being to approximate aspects of a teachers' embodied experiences. In this paper, we focus on one form of VR: 360-degree video. Specifically, we conjecture that teacher noticing is an embodied activity where teachers' perceptions of occurrences in the classroom is mediated by their physical senses and actions, and 360-degree videos may provide an opportunity to explore this relationship. Indeed, various forms of VR allow for examination of a portion of such physical actions, such as preservice teachers' (PSTs) field of view (Huang, Richter, et al., 2021; Kosko, Ferdig, & Zolfaghari, 2021). The purpose of this paper is to examine the interaction between PSTs' self-selected field of view and their teacher noticing. Specifically, we recorded the viewing sessions of PSTs as they watched a 360-degree video while wearing a VR headset. We then analyzed PSTs' written noticings to examine the connections between their embodied linguistic metaphors and their embodied actions.

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1. Teacher noticing

Teachers' professional noticing involves identifying and attending to what is important in a pedagogical context, interpreting these specific instances with "broader principles of teaching and learning" (van Es & Sherin, 2002, p. 573), and then deciding how to respond to these specific instances (Jacobs et al., 2010; Rosaen et al., 2008; van Es & Sherin, 2002). Thus, professional noticing both informs (Lee, 2017) and is informed by (Dick, 2017) teachers' professional knowledge regarding the content they teach and the pedagogy to teach said content (i.e., pedagogical content knowledge). For the purposes of this study, we focus on the first aspect of noticing described above: attending. van Es and Sherin (2002) note that teaching is such a complex activity that it is impossible for teachers to respond to everything happening in the classroom. In fact, it is the complexity of what and how teachers attend in their professional noticing that has led to the overwhelming use of standard video in studying the construct (Rosaen et al., 2008; van Es & Sherin, 2002).

Novice, preservice teachers (PSTs) have been observed to attend to video of classroom instruction differently than more experienced teachers (Jacobs et al., 2010; Krull et al., 2007).

For example, Krull et al. (2007) found that experienced teachers noticed more specific student actions in a grammar lesson and described them in more detail than novice teachers. Jacobs et al. (2010) reported a similar observation in the context of elementary grades mathematics. Responding to a video in which children solved 43×6 , more experienced teachers attended to decomposition of place value by the children in the video (e.g., 40×6 & 3×6), as well as noting the use of benchmark numbers. By contrast, teachers with more generic descriptions noted the child wrote specific numerals and added in a particular order but did not describe aspects of place value or benchmark numbers. Both place value and use of benchmark numbers are common conceptual tools that students can learn developmentally, and teachers can use pedagogically. Thus, they are generalizable, and not generic, aspects of pedagogical content knowledge. Other scholars have found similar relationships in comparing experienced and novice teachers' noticing across multiple disciplines (Beach et al., 2019; Huang & Li, 2012; Plöger et al., 2019; van den Bogert et al., 2014).

Examining PSTs' noticing of science classrooms, Barnhart and van Es (2015) developed three levels of sophistication for noticing skills. Low sophistication is designated by attending to "classroom events, teacher pedagogy, student behavior, and/or classroom climate (p. 87), but with no apparent focus on student thinking. Medium sophistication is designated by attention to student thinking, but with a focus on procedural reasoning. A high sophistication is designated by focusing on students' conceptual thinking (i.e., analysis and interpretation). This progression in attending is similar to those observed by others (Beach et al., 2019; Rosaen et al., 2008; van Es & Sherin, 2002). Thus, regardless of the content area and pedagogical focus, there appears to be a consensus across the literature of how professional attending develops. Specifically, attending may initially be more general with less specific attention to important events, and focus on more surface-level details of pedagogy (i.e., classroom management, student behavior). Advanced attending is demonstrated by specific attention to key events with descriptions of those events that correspond to generalizable aspects of professional knowledge, such as the example from Jacobs et al. (2010) in the previous paragraph.

2. Examining teacher noticing as embodied

"Thinking involves the reactivation and reuse of processes and representations involved in perception and action" (Fincher-Kiefer, 2019, p. 10). A large body of research supports this notion of cognition as embodied. For example, when shown videos of simple tool use (saws/sawing, hammers/hammering), fMRI data from participants indicated that areas of the brain related to the sensory-motor aspects of the activity depicted were activated while viewing the video (Beauchamp & Martin, 2007). Further fMRI research by Boronat et al. (2005) found that when participants saw the written words related to a physical manipulation, the respective neural networks related to such physical manipulation were activated. Lakoff and Johnson (1980) suggested that language often serves as

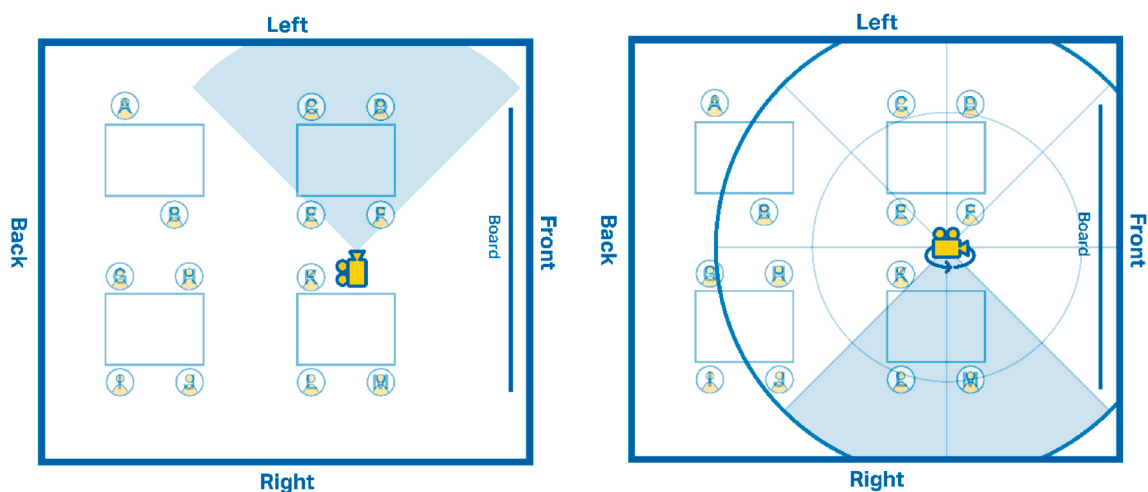


Fig. 1. What is perceivable from a standard video (left) versus a 360-degree video (right).

metaphors for such embodied activity. For example, things valued as good are often described in English as *up* and things less valued as *down* (Lakoff & Johnson, 1980). In the context of education, one may describe a student's reasoning as *below* average (down), as a *high* achiever (up), etc. Although useful examples, examination of professional noticing in teaching or any other specialized field likely incorporates different metaphors and functional grammar due to how professional knowledge is embodied. If teacher noticing, and the professional knowledge used to facilitate it, are embodied, then those individuals with more sophisticated noticing and knowledge should demonstrate different physical actions while engaged in noticing than those with less sophistication. There is a growing body of literature incorporating eye-tracking when teachers watch standard videos that lends support for this conjecture. Specifically, experienced teachers are able to scan students in a classroom more quickly and are able to focus on specific students/events more, while novices' eye-tracked gaze behavior is more erratic (Dessus et al., 2016; Grub et al., 2020; Huang, Miller, et al., 2021; van den Bogert et al., 2014). Eye-tracking data suggests teachers with less experience attempt to focus on multiple students, whereas experienced teachers perceive all students but focus on a more select group (Dessus et al., 2016; Huang, Miller, et al., 2021). Yet, even when novice and experienced teachers appear to attend to the same sorts of events in a classroom, their focus on such events differs (Pouta et al., 2020).

Supporting findings from the aforementioned eye-tracking literature, scholars have begun to use screen recordings of PSTs' attending in VR sessions (Ferdig, Kosko, & Gandolfi, 2020; Kosko et al., 2021; Gold & Windscheid, 2020; Huang, Miller, et al., 2021), including 360-degree video. As a medium, 360-degree video differentiates itself from traditional video by recording in a spherical direction. Thus, the viewer chooses which direction they look, as opposed to having the direction chosen a priori (see Fig. 1). This allows for a greater sense of immersion (Ferdig & Kosko, 2020; Roche & Gal-Petitfaux, 2017), with evidence that some teachers attend to more student actions with greater specificity than if viewing a standard video (Author et al., 2021b).

2.1. Using 360-degree video to examine embodied teacher noticing

Beyond the benefits presented in the emerging body of literature on 360-degree video in teacher education research, the medium, as a form of non-interactive VR, also provides an opportunity to investigate more fundamental theoretical aspects of teacher noticing (Huang, Miller, et al., 2021). Author et al. (2021b) compared the PSTs' attending when viewing the same recorded scenario via standard video, 360-degree video on a laptop, and 360-degree video on a VR headset. They found that the more immersive the view, the more student actions PSTs described. Contrasting this finding, Gold and Windscheid (2020) compared PSTs' viewing of standard video and 360-degree video on a laptop, but observed no significant differences in the number of student actions observed in either condition. However, both studies had several key differences that could contribute to the seemingly contrasting results including different camera placements and editing of the standard video format, and different kinds of tasks being asked of PSTs (observing content-based actions versus observing classroom management events).

Both Huang, Richter, et al. (2021) and Ferdig et al. (2020) provide more explicit descriptions of how PSTs' bodily movements relate to how they attend to classroom-based events. Huang, Richter, et al. (2021) found that PSTs wearing VR headsets in a digital classroom scenario were less likely to attend to key classroom management events when they were tasked with giving a lecture versus monitoring students in the class. Additionally, the more disruptive events included in a VR scenario, the less likely PSTs were observed to respond to such disruptions (Huang, Richter, et al., 2021). Author et al. (2020b) compared where PSTs' attended in a 360-degree video of a classroom with four group tables when PSTs viewed the video with either monophonic or ambisonic audio. Monophonic audio records audio with one channel (standard audio) whereas ambisonic audio records with at least four channels and conveys directionality of sound that is synched with where the 360-degree video perspective is adjusted by the viewer. PSTs viewing the 360-degree video with ambisonic audio focused on two tables with significantly higher frequency, whereas monophonic participants had larger variability in where they turned their camera perspective. Although the findings from Huang, Richter, et al. (2021) and Author et al. (2020b) may seem to contradict each other, both studies focused on different aspects of classroom practice. Author et al.'s (2020b) findings suggest that ambisonic audio is more immersive and allows PSTs to focus more within a given scenario. Huang et al.'s (2021b) findings suggest that, once within a classroom scenario, the intensity of classroom disruptions, the task of teaching PSTs are engaged, and the decision of whether to respond to disruptions all interact. In each context, however, both sets of scholars have observed that the manner in which PSTs adjust their bodily perspective relates to how they attend to classroom events.

3. Overview and research question

When asked to engage in teacher noticing, experienced and knowledgeable teachers attend more to student actions and do so with more focus and depth of description than novices (Barnhart & van Es, 2015; Dessus et al., 2016; Jacobs et al., 2010). Engaging PSTs in teacher noticing tasks with 360-degree videos has been observed to increase their ability to engage in such sophisticated attending actions (Author et al., 2021b; Theelen et al., 2019; Walshe & Driver, 2019). Yet, simply providing PSTs with 360-degree videos is not sufficient to improve their ability to professionally notice (Zolfaghari, Austin, Kosko, & Ferdig, 2020; Roche & Rolland, 2020). There is a significant need to better understand the embodied nature of how PSTs engage in professional noticing. Similar to Huang et al.'s (2021b) advocacy of VR as a testbed for teacher education research, we consider 360-degree video and other forms of VR as a means for investigating patterns in professional noticing. To do this, we conjecture that what PSTs identify as significant and how they describe such attended events in writing correspond to their demonstrable, embodied actions when viewing 360-degree video with a VR headset. We describe this relationship as interactive, in that it is likely to be bi-directional. To explore this conjecture, we sought to answer the following research question:

How do PSTs' recorded movements in a 360-degree video of classroom practice relate to the moments they attend to in writing?

4. Methods

4.1. Sample

The sample included 44 PSTs enrolled in a Midwestern U.S. university. Participants were education majors completing a required course on educational technology, and represented a variety of education majors including: secondary (ages 14–18) English (15.9%), mathematics (6.8%), science (2.3%), and social studies (20.5%); middle childhood (ages 9–14) mathematics/science (4.5%) and English/social studies (4.5%); early childhood (ages 3–9; 15.9%); art education (15.9%), and various other foci (American Sign Language; Foreign Language Education; Special Education; School Health). The participants ranged in age from 19 to 23 years of age ($M = 20.31$, $SD = 0.96$), and included individuals across academic rank (Freshmen = 2.3%; Sophomores = 29.5%; Juniors = 56.8%; Seniors = 11.4%). Most participants identified as White (90.9%) and female (63.6%), with 54.5% of the sample identifying explicitly as White female, 36.4% as White male, 6.8% as Black female, and one student (2.3%) as Hispanic female.

Given that this study used a technology that may be considered by some participants as relatively novel, data were also collected regarding participants' familiarity with technology, in general, and 360-degree video, in particular. Asked to report how "tech savvy" they perceived themselves to be, on a scale from 1 to 10, participants generally rated themselves as average ($M = 5.95$; $SD = 1.67$). Half of participants reported having used a virtual reality (VR) headset prior to participating, with 59.1% reporting having watched a 360-degree video previously.

4.2. Procedure

Participants were recruited from an undergraduate research pool at the authors' university and were each enrolled in the same educational technology course. After completing the consent process, participants completed a short demographic survey. Next, they were shown how to use the headset mounted display, or virtual reality (VR) headset in the form of the Oculus Go. Participants were provided an illustrated walkthrough of how to record their viewing session on the headset and then watch 360-degree videos selected for the study by the researchers. The printed "step by step" guide was provided in addition to one-on-one guidance from project personnel. Participants were tasked with beginning screen recording and then watching both videos stored on the Oculus Go headsets.

Participants first watched a brief tutorial video, since first-time users of 360-degree video do not always realize they can or should adjust their perspective (left, right, up, down, etc.) to look around. The brief video engaged PSTs in looking for specific objects or actions in a 360 scenario. The second video (6 min and 58 s) was the primary focus of the study. It recorded a whole class activity with 3rd grade students (8–9 years old) addressing the Commutative Property of Multiplication. Students used Cuisenaire rods, a color-coded length model for lengths of 1–10 (white rods = 1 cm; red rods = 2 cm; light green = 3 cm, etc.), to cover a 7 cm by 8 cm array with only one color of rod. Following exploration with covering the array, students provided different strategies to cover the array precisely.

After watching both videos, participants removed their VR headsets and ended the recording of their viewing session. They were then asked to "describe any and all pivotal moments you noticed during the lesson (i.e., any moment you believe is important for the teaching and/or learning of mathematics)." After writing this response, participants were asked to "select ONE pivotal moment that you noticed (important for teaching and/or learning of math). Describe the moment and explain why it is important." Participants' written responses were scanned and then transcribed for analysis.

4.3. Analysis

4.3.1. Written noticings

Participants' written responses were analyzed using a Systemic Functional Linguistics (SFL) approach (Eggins, 2004; Halliday & Matthiessen, 2014), a form of discourse analysis. SFL focuses on how grammar in language functions to convey meaning. This analytic framework allowed for examination of functional grammar participants used in describing their perceived pivotal moments from the 360-degree video. The primary unit of analysis in SFL is the clause, with the relationship between two or more clauses conveyed through cohesion (Halliday and Matthiessen, 2004). Cohesion is when two different elements of the text are connected thereby establishing meaning and can be conveyed through different grammatical resources. For the purposes of this study, we focus on the system of reference. A *reference* cannot be semantically interpreted on its own and refers to other aspects of the text (Halliday & Hasan, 1976). The repeated referencing to these items forms what are known as referential chains (Eggins, 2004). Participants' referential chains or clauses were analyzed with attention to the transitive and nominal groupings. Nominal words represent an object or entity and reveal the actor or goal in a clause (Halliday, 2014). A transitive word can be thought of as transferring the action onto someone or something. This is illustrated in the text below where nominal groups are underlined, transitive processes are bold, and each clause is separated by//.

The students **stacked** the blocks together in groups.//

After stacking the blocks the students **realized**//they could **stack** evenly together.

In the first sentence, the nominal element "students" is conveyed to act upon the blocks through the transitive process "stacked." This stacking of blocks by students serves as a reference, which continues in the second sentence with the interactant "students" conveyed by a different transitive process "realized". Transitive groups give representational meaning about the process of transfer

while nominal groups convey the actor or goals of the clause.

The identified referential chains suggested nine specific themes emergent from the texts. The second and third author reviewed writing samples to verify whether each of the nine themes was conveyed (a writing sample could convey multiple themes). We used Cohen's Kappa as an indicator for reliability, as this statistic checks against agreement by chance for themes that emerged from PSTs' written text (teacher movement = 0.877; commutativity = 0.685; student thinking = 0.815; student discussion = 0.506; student investigation = 0.868; hands-on learning = 0.761; group work = .757; call-and-response = .816; and valuing video format = 1.00). While student discussion was found to have moderate agreement, all other themes were found to have substantial (0.61–0.80) or near perfect (0.81–1.00) agreement (Landis & Koch, 1977).

4.3.2. Participants' 360-degree video field of view (FOV)

Participants were asked to record their viewing experience when wearing the VR headsets. These recordings allowed us to examine where and when participants turned their head in the 360-degree video. Although this allowed researchers to understand what was in a participant's field of view (FOV), we were unable to pinpoint what specifically participants looked at within their FOV. Similar to the approach used by Huang, Richter, et al. (2021), we examined recordings for presence of specific events within participants' FOV. The map of the recorded classroom used in this study is shown in Fig. 2, along with an illustrative comparison of how participants' FOV may vary for a particular moment in the recorded lesson.

Analysis of participants' FOV involved two stages. First, we examined for presence of the teacher in participants' FOV second-by-second of their viewing experience. Recall that more sophisticated teacher noticing involves attending more to student actions than the classroom teacher (Huang & Li, 2012; van den Bogert et al., 2014). By analyzing for presence of the teacher within the FOV, we sought a preliminary indicator for patterns of teacher-focused versus student-focused attending. Next, we examined the second-by-second indicators of teacher presence in FOV for patterns. For example, since the teacher moved about the classroom throughout the lesson, a PST with long stretches of teacher presence in their FOV may be considered as tracking the teacher. In such cases (sustained periods with or without teacher presence observed) comparison across participants were made to determine if such patterns within one participant's viewing corresponded with a pattern to those of peers. This allowed for identification of key segments where distinct

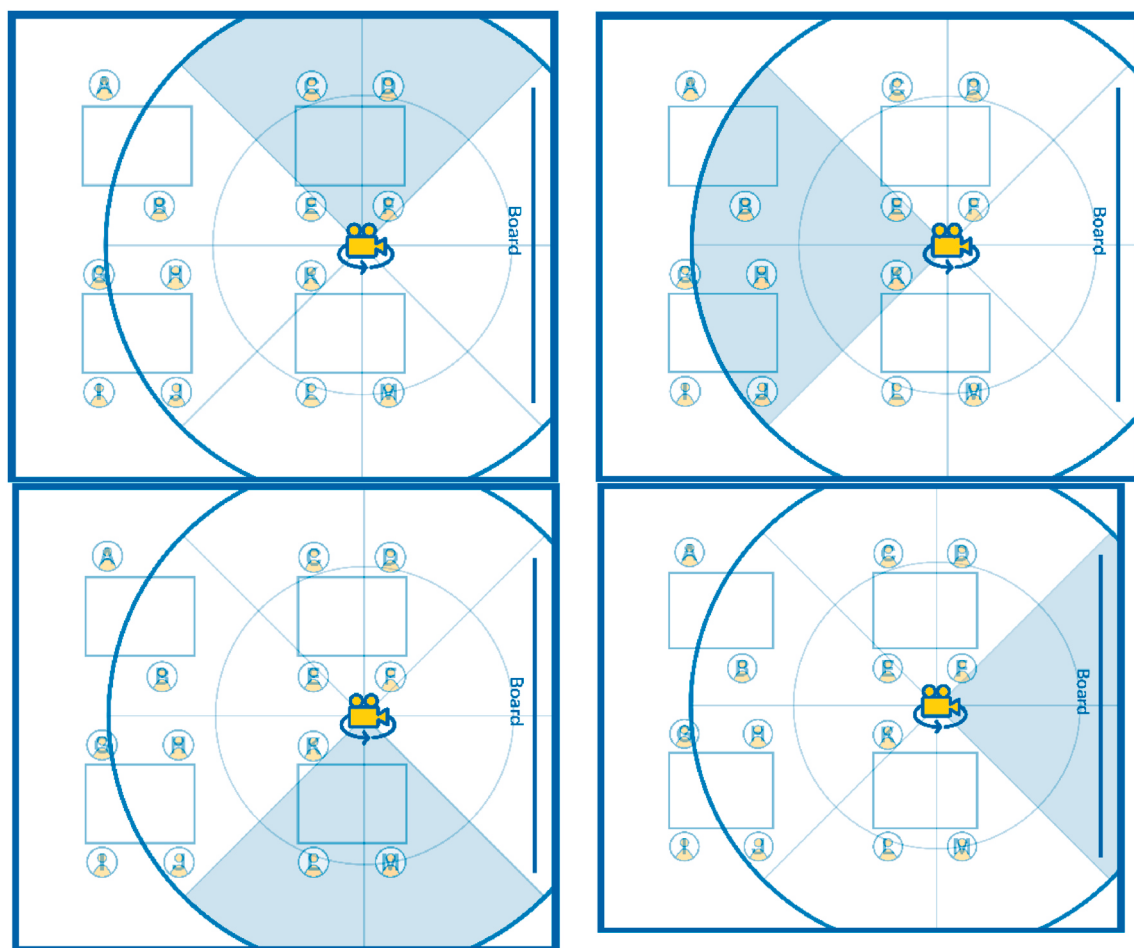


Fig. 2. Illustrative example of different perspectives and what is perceivable in each FOV.

viewing patterns emerged. Then these key segments were reviewed (re-watched) by each author to identify patterns (or themes) for events within each participants' FOV. A description of this portion of the analysis is provided alongside findings later in this paper.

There were 420 s intervals per participant (recall the 360-degree video was 6 min 59 s). Each second was coded for the presence or absence of the teacher within the FOV (0 = not present; 1 = present). Presence of the teacher in participants' FOV ranged from 34.8% to 83.3% of the video ($M = 0.582$, $SD = 0.119$). This variance, illustrated in Fig. 3, indicates there are segments of the timeframe where nearly all PSTs include, or don't include, the teacher. As previously noted, we explored PSTs' FOV patterns for periods of time that may warrant further analysis. To facilitate this, we used emergent themes from PSTs' written noticings to help identify which patterns in the FOV data to examine further. Subsequent examination of the video segments themselves allowed for study of any potential relationship between what was linguistically referenced in writing and what was present within participants' FOV.

5. Findings

5.1. Emergent themes in written noticings

Written noticings were examined for emergent themes in how reference was used to convey meaning. Specifically, we sought to understand how reference chains conveyed important aspects of participants' professional noticings. Nine themes emerged referencing teacher movement, commutativity, student thinking, student discussion, student investigation, hands-on learning, group work, call-and-response, and valuing video format.

Teacher movement included references to the teacher walking or moving about the classroom and was the most prevalent theme with 43.2% of participants including it in their writing. As evidenced by the response below, references to teacher movement coincided with particular scaffolding moves. In some instances, such scaffolding moves were associated with references to other emergent themes. However, no consistent trend emerged in such occurrences.

The teacher **was moving** all around the classroom//

and he **was asking** students

to work together.//

He **was trying** to show the kids that 8×7 and 7×8 was the same thing.//

He **asked** them

to take 8 brown block//

Commutativity emerged as a theme where participants referenced various aspects of the Commutativity Property of Multiplication. Considering that the entire activity focused on the Commutative Property of Multiplication, this percentage may seem low. The response shown in Fig. 4 illustrates this theme where the participant conveys students' discovering that "[seven] 8 blocks is the same as [eight] 7 blocks" as "the most important pivotal moment." This reference is included twice by the participant, with their second mention positing the rationale that students "made a connection between the mathematical concept and the activity." The commutativity theme emerged in 38.6% ($n = 17$) participants' responses. Of note is a tendency for references to commutativity to coincide with references to student thinking, another emergent theme. Both themes were observed independently (15.9% for *commutativity* & 15.9% for *student thinking*) nearly as often as they were observed to co-occur across all participants' responses (22.7%), but it was a pattern that was noted for later video analysis.

Student thinking was typically characterized by mental processes (verbs) linked to student actors (nominal objects). In SFL, the role that nominal objects (such as actor and goal) play are associated in relation, or reference, to one another (Halliday & Matthiessen, 2014). In the example below, student thinking is indicated as referenced by "when the students **realized** that//the different size and quantities of blocks fit together." Here, 'students' serves as the actor, which the grammatical process 'realized' positions in relation to the goal of these actors understanding that "different size and quantities of blocks" are the same. The theme emerged in 38.6% of participants. As noted earlier, in over half of the occurrences of this theme, clauses that referenced student thinking also included a referent to commutativity.

The most important pivotal moment **was probably** when the students **realized** that//the different size and quantities of blocks **fit** together//

because they **made** a connection between the mathematical concept and the activity.

Notably, instances where participants did not reference commutativity with student thinking were also common. Such instances were characterized with references towards the mathematical task in the lesson, but not necessarily with the specificity needed to articulate recognition of commutativity. For example, one participant wrote:

[One pivotal moment was] The problem solving to **figure out** the different colors and number of blocks in a square//to **figure** how many blocks they need to fit in the square.

The next theme that emerged was *student discussion*, which was conveyed through reference to students discussing the mathematics in the video. The below participant response illustrates a typical example of this theme, where the PST not only references *discussion*, but contextualizes what the discussion is about. This contextualized referencing is consistent across all participants where this theme emerged (11.4% of participants).

Discussion about the brown and black squares [is a pivotal moment].

[teacher] **Rephrasing** of question [is a pivotal moment].//

when students **had** trouble.

Individual and group work and/or collaboration. [is a pivotal moment].//

One-on-one help with teacher as needed [is a pivotal moment].

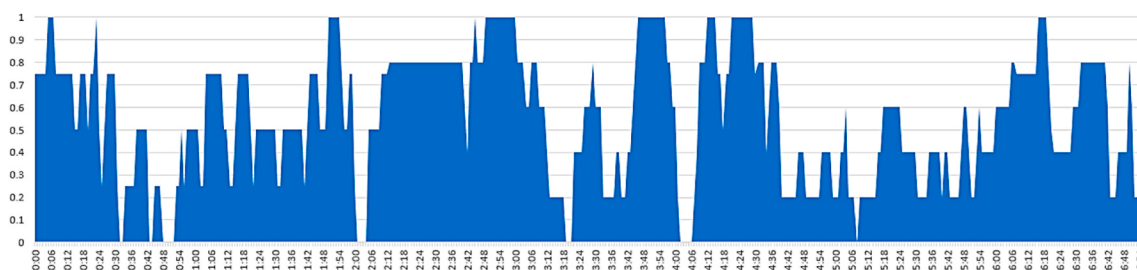


Fig. 3. Portion of participants including teacher in their field of view throughout the video.

Experimenting with the blocks.
 Discovering that 7 8 blocks is the same as
 8 7 blocks.
 Students being able to explain their thought processes
 The most important pivotal moment was probably
 when the students realized that the different size and
 quantities of blocks fit together because they made
 a connection between the mathematical concept and
 the activity.

Fig. 4. Side-by-side comparison of written noticing and transcribed, coded theme.

Another theme that emerged was that of *student investigation*. This theme was realized through references to transitive processes such as experimenting, exploring, or using. These processes were generally paired with reference to the manipulatives or models used, and such clauses were often enhanced through references to allowing students to fail, trial and error, and so forth. For example, one participant wrote:

Students got to explore math on their own and//
 [The students got to] use the tools they had
 to make connections to the numbers.

In this example, the “student” is in the nominal group and “explore” is the transitive process pointing towards the goal of “math.” Further, the clause is enhanced with “on their own,” indicating a more autonomous exploration. The processes of “use” and “make” incorporated later serve to continue this reference chain with similar emphasis and enhancements. This combination creates grammatical cohesion that allowed for interpretation of the theme. Student investigation was found in 20.5% of PSTs’ written noticings.

Whereas the student investigation theme is considered an observation of internal processes by students, the *hands-on* theme is considered an external observation. Transitive groups such as “use of manipulatives”, “hands-on”, or “using the blocks” were identified in this theme. An example of the hands-on theme can be seen below. PSTs’ patterns of noticing regarding hands-on learning occurred 29.6% of the time.

I also noticed//that the lesson was hands on,
using the blocks to count.
This [using blocks to count] can be good
for students who are hands on learners.

The *group work* theme is identified through the nominal phrasing of “groups” that was then tied in with the group work aspect through the transitive words “allows”, “communicate” and “help”. Other nominal objects or groups that were observed for this theme included descriptions of teamwork, peer help, sharing and working together. For example, one participant wrote, “Also, the fact that the students were in groups instead of individual desks allows them to communicate and help each other out.” The group work theme was conveyed from 15.9% of participants.

Call-and-response emerged as a theme associated with the teacher calling on students to focus. The most prevalent reference used in this theme was the teacher’s use of asking students to put their finger on their nose if they could hear him. The participant’s written noticing below exemplifies this attention to the teacher’s scaffolding. Here, the call-and-response move was referenced, by the participant, toward the goal of ‘re-centering’ the class for discussion. This theme was observed in 11.4% of participants.

I like how the teacher brought the students back in for discussion//by having them put their finger on their nose//It was a calm and effective way to re-center.

The theme *value video format* emerged when participants referenced the 360-degree video experience in comparison with a standard video viewing experience. For example, in the below response, the participant referenced “a normal video” with a comparative value judgement positioning the 360-degree video as preferred. Notably, 360-degree video is elipsed as an explicit

reference, but is alluded to in subsequent references to “turn my head” and “follow him” which point to the feature of adjusting one’s perspective in 360-degree video. 13.6% of participants conveyed this theme.

I felt way more engaged//
with what he [teacher] was teaching//
than if I **had just watched a normal video**//
because I **had to turn my head**
and follow him.

5.1.1.1. Themes as referents to embodied noticing

The observed themes were manifested in written text that could be explicitly framed, as we have done in the preceding paragraphs. Examining how, or whether, these linguistic referents pointed to participants’ noticings required a stepwise process. Recall that each participants’ recorded noticing was watched and analyzed for when and whether the teacher was in the FOV. This allowed for a preliminary analysis of periods of time within the 360-degree video to be identified where a theme from written noticing aligned with presence or absence of the teacher in the FOV. This resulted in approximately 16 segments, which were analyzed further for common occurrences within participants’ FOV. Half of these segments were identified as having commonalities due to emergent themes,¹ and we discuss four such segments below to characterize the nature of such interactions (between linguistic themes and participants’ FOV). In describing these interactions, we discuss the events within each episode and observed correspondence between presence or absence of specific themes from written noticings.

5.1.1.2. Initial group work [0:45 to 1:14]

Following an initial prompt by the teacher, students began working in their small groups to find one color rod to cover the 8 by 7 array. As students worked, the teacher moved around the room examining students’ strategies to cover the array. During this portion of the video, participants who conveyed the themes commutativity and student thinking in their written noticing included the table in the front-left portion of the room in their FOV (see Fig. 6). Participants who conveyed valuing the video format tended to focus on a specific moment where two students (E & F) stated they did not want to share rods after the teacher’s suggestion.² Other participants appeared to divide their attention to other tables or other parts of the room.

Participants who noticed group work in their writing tended to center students at one of the two front tables in their FOV, while the teacher attended to them (see Fig. 5). As these PSTs were attending to the students, they simultaneously would glance at the teacher when the teacher addressed the group (shift FOV back-and-forth); keeping the students centered in their FOV. Additionally, immediately preceding this segment, participants linked with the group work theme appeared to track the teacher as he walked to the different groups. Thus, placing the teacher in one’s FOV as he provided instruction for the work appeared to facilitate participants’ centering their FOV on students and then describing their group work.

5.2. Two students share strategies [2:04 to 2:40]

Following students’ investigation with the rods, the teacher asked two students, L and M (see Fig. 6), to share their strategies for covering the entire 8 by 7 array. Student M shared his strategy of eight black rods (8 rods of 7) as the teacher wrote it on the board. Student L then shared her strategy of seven brown rods (7 rods of 8) as the teacher wrote it on the board. This exchange (2:04 to 2:40) preceded the teacher drawing attention to the students’ strategies as a benchmark for the next phase of the activity (having the class explore whether one set of rods will fit exactly on top of the other).

Analysis of participants’ 360 viewing during this interval suggests subtle but distinctive differences in how PSTs adjusted their FOV. These subtleties appear to align with themes from PSTs’ written noticings. First, participants who conveyed commutativity, student thinking, and the call-and-response themes adjusted their FOV in ways that included the teacher less frequently. Consider Fig. 7 in which an image is taken from two participants at the same point in the recorded lesson (when student M is clarifying the length of her rods). The right-hand image is from a participant who conveyed commutativity and student thinking in their written noticings, whereas the left-hand image is from a participant conveying neither theme. Apparent in this set of still images is the position of the teacher within the FOV. Participants who conveyed commutativity tended to include both students L and M in their FOV when those students were speaking. Moreover, these students were often positioned closer to the center of participants’ FOV than the teacher was positioned. This tendency was also observed with participants who conveyed student thinking and call-and-response. By contrast, PSTs who did not convey commutativity were less likely to include students L and M in their FOV. If included, the students were further from the center of their FOV than participants who did convey commutativity. This was particularly obvious regarding student M and her contributions to the class discourse.

5.3. Teacher scaffolding during group work [3:12–3:59]

This segment follows a prompt by the teacher for students to explore whether a rectangle of 7 rods of 8 would fit on top of a

¹ It is possible that meaningful patterns exist in such data, but such patterns were not readily observable. As such, we excluded them from further analysis.

² This particular exchange was a humorous one between the students and was not confrontational or negative.



Fig. 5. Two participants viewings of the front-left (left) and front-right (right) tables when the teacher is talking with students.

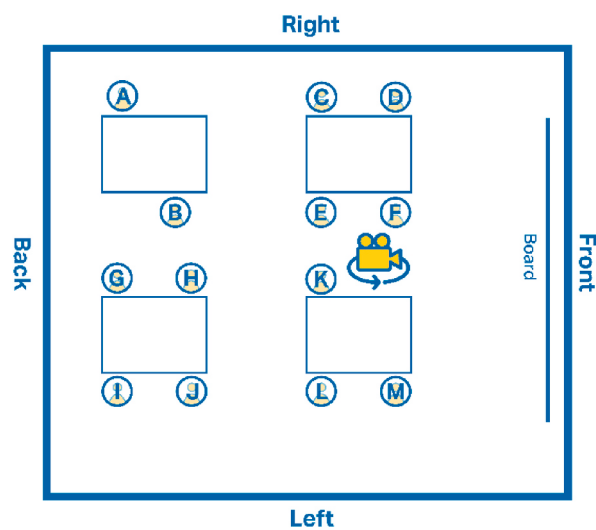


Fig. 6. Diagram of the classroom layout, with letters designating students.



Fig. 7. Side-by-side comparison of the same frame for a participant with the teacher in the center frame (left) and where the teacher is off-center (right).

rectangle of 8 rods of 7, after students predicted it would not. At around 3:20, the teacher writes on the board the rods to stack and compare. At 3:40, the teacher puts his finger on his nose (call-and-response), and draws attention to the back-left table, where he clarifies what he means by “stacking” the rods with an emphasis for students to keep the rectangles composed of rods together. This segment ends with such scaffolding, and students continue to work in their groups.

Participants who referenced student investigation in their writing included the teacher in their FOV as the teacher moved around the room and scaffolded instruction (i.e., writing on the board, clarifying how to stack the rods). In a similar manner, participants referencing the group work theme in their writing focused on the teacher when he provided instructions for how the tables were to work together to stack the 8 black rods (length 7) on top of the 7 brown rods (length 8).

5.4. Discussing why stacking the rods worked [5:50 to 6:28]

This segment of the lesson included a portion of the whole class discussion for why stacking the two sets of rods worked. At one point, student H suggested it worked “because the array is seven down and eight across.” This segment begins following the teacher’s press for student H to tell him more about that. Specifically, at 5:50, student F shared her reasoning. When pressed to explain more by the teacher, student F shared that you can add “one more” to each 7 and take one from each 8 to make it work. Mathematically, this is significant because it implicitly conveys using associativity to explain why commutativity works.

Similar to the segment earlier in the lesson [2:04 to 2:40] participants who conveyed commutativity centered student F more in their FOV than other participants who also adjusted their perspective to turn towards her (see Fig. 8). Participants who conveyed the teacher’s movement [6:07 to 6:09] and student discussion [5:50 to 5:57] themes in their written noticings tended to focus on the teacher early in this segment [6:07–6:09], whereas participants conveying commutativity did not. This is a portion of the video where the teacher establishes the topic of class discussion. However, the finding is similar to those from the earlier segment in the lesson [2:04 to 2:40] suggesting commutativity is a student-centered theme (i.e., those attending to it centered students in their FOV). Although only the back of student F’s head was visible here, participants who wrote about commutativity consistently centered her in their FOV. Immediately following the exchange between the teacher and Student F, Student E contributes to the whole class discussion stating that “the numbers are the same, it’s just one is on the other, so you just have to flip this to the other side.” The manner that participants attended to this moment appeared related to whether they identified *student discussion* as a pivotal moment. Rather, participants who incorporated different students describing their mathematics as centered in their FOV also wrote about student discussion as something they noticed.

6. Discussion

This study focused on how PSTs’ professional noticing, as evidenced from their written responses, corresponded with how they moved within a 360-degree video VR experience, as evidenced by recordings of their FOV. Findings suggest that what and how PSTs notice, while viewing a 360-degree video with a VR headset, is related to what they describe in their written noticings. Specifically, findings suggest that how specific types of pedagogical events are framed (by the participants’ FOV) may have influenced whether and how *perceived* moments were *attended* to by participants in their writing. Given that interpretation of such attended events is influenced by experience and professional knowledge (Pouta et al., 2020), more research is needed to better understand such interactions. The findings of the present study lend support to an observable relationship between teachers’ embodied actions and their professional noticing, but there is a need to understand how teachers’ knowledge, beliefs, and experiences influence such a relationship. Rather, we conjecture that teachers’ interpretation of attended events is both influenced by and influences their professional knowledge, and that such an interplay is embodied. Yet, as previously noted, further scholarship is needed to better understand and unpack this interplay at both a theoretical and empirical level.

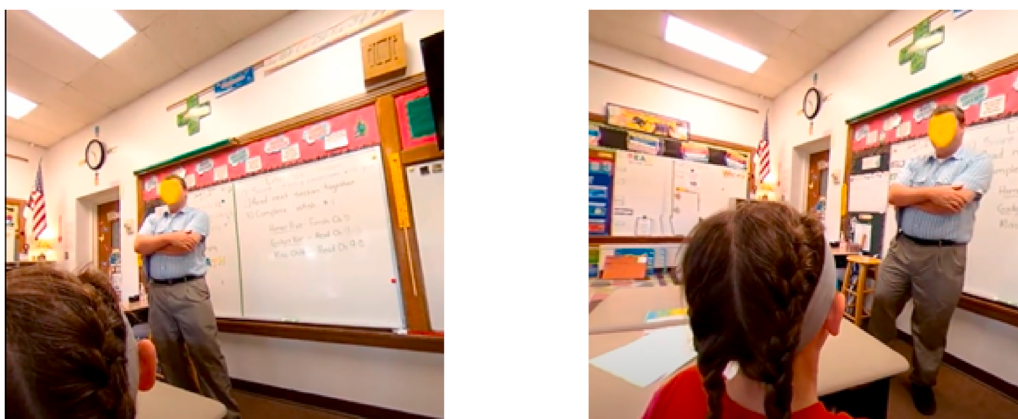


Fig. 8. Side-by-side comparison of the same frame for a participant with the teacher in the center frame (left) and where the teacher is off-center (right).

It is doubtful that participants viewed the 360-degree video without having seen (perceived) students stacking the rods or discussing such stacking given the prevalence of such activity in the recording. Yet, less than half (38.6%) attended to this moment in their written noticings. Analysis of VR headset recordings in the 360-degree video suggests two simultaneous actions were essential for whether participants described the Commutative Property and students' thinking as moments of pedagogical significance. One such action was including students within one's FOV when they were describing mathematics. The other action was positioning these students in the *center* of one's FOV during whole class discussions. When students weren't centered in the FOV, participants were less likely to attend to the mathematics content or students' thinking in their writing. Such findings support and extend those from prior research which point to a need for focusing on students' content-specific actions in classroom videos (Barnhart & van Es, 2015; Beach et al., 2019; Jacobs et al., 2010; Rosaen et al., 2008). Rather, if attending to content is an objective in teacher noticing, findings presented here indicate a need to emphasize students' voices as *literally* central to what PSTs should focus.

One unanticipated finding in comparing PSTs' written noticings with how they watched the 360-degree video related to the centrality of students within the FOV for the commutativity theme. Notably, two such episodes included two girls who contributed to the mathematics discussions. Within each of these discussions, other students at the front two tables, as well as the back two tables, did contribute to classroom discussion. However, these were the only two girls at the front two tables (M was the only black student in the class) and represented half the female students in the video (two of four girls out of 14 total students). Similar to findings of gendered norms for classroom participation by teachers and students, it is possible that some PSTs' professional noticing may be gendered to privilege mathematical actions of males over females (Leyva, 2017). Analysis of such gendered noticing was not an objective of this study, and this finding should be interpreted as preliminary and in need of further study. However, this preliminary finding does suggest studying PSTs' FOV in 360-degree video viewing has significant potential for studying this and similar phenomena. Additionally, 360-degree video may serve as potential feedback tool for PSTs engaging in such noticing behaviors without awareness of doing so.

Some emergent themes examined here are often associated with attending to students (student discussion, student investigation, hands-on learning, group work). However, evidence presented in this study suggests attending to these themes often corresponded with including the teacher within one's FOV. For example, the theme student investigation appears, on its surface, to be a student-focused practice for PSTs to attend. However, findings suggest PSTs who describe this theme in writing tended to follow the teacher's movements at specific portions of the video. One potential explanation for this observation stems from the written noticings. One participant demonstrating this theme wrote as a justification for student investigation that:

The students **got** the chance to come up with an answer on their own//because the teacher **guided them** in the right direction.

Therefore, it seems that including teacher's scaffolding in their FOV may have facilitated participants' descriptions of student investigation. Each of these themes (student discussion, student investigation, hands-on learning, group work) appeared to follow a similar trend, leading us to conjecture a common pattern between attending to teacher scaffolding events and referencing these themes. This potential association should be confirmed by future research, and differentiated from when PSTs should attend to students' actions instead (Jacobs et al., 2010; Levin et al., 2009; van den Bogert et al., 2014).

Observed interactions between PSTs' written noticing and their recorded movements (adjusted FOV) in a 360-degree video of classroom practice provides several implications for theory and practice. First, both the manner and form of positioning teachers and/or students in one's FOV is related to what PSTs attend to, in writing, as pedagogically significant. Such a finding is nontrivial, since it indicates that the direction a teacher chooses to turn their head, as well as when and how they do so, is a determining factor in how they interpret classroom events. Beyond adding to scholarly evidence that teacher noticing is embodied activity (van den Bogert et al., 2014; Dessus et al., 2016; Huang, Miller, et al., 2021), this provides additional evidence for *how* such noticing is embodied. For example, students' discussion of their strategies and rationales for why stacking the rods conveyed $7 \times 8 = 8 \times 7$ within the 360-degree video was a reference to the actual activity of stacking the rods. All participants included students stacking the rods within their FOV at various points, but only those who centered students within their FOV in describing their strategies were the ones who discussed commutativity in their written noticings. Thus, perceiving a specific student action may not be sufficient for whether a PST attends to it within a recorded, or actual, classroom. Rather, it is positioning students' reasoning about such actions as, literally, central that may determine whether such content-specific noticings take place.

An important implication for researchers investigating the embodied nature of teacher noticing is to identify additional features of moments that relate to either content-specific or more general aspects of pedagogy. The present study used change in FOV as signified by PSTs turning their heads while wearing a VR headset. However, physiological evidence may stem from variation in how sound is recorded in a scenario (Author et al., 2020b), eye tracking data (van den Bogert et al., 2014; Dessus et al., 2016; Huang, Miller, et al., 2021), haptic interactions, or some other form of embodied sense. As certain technologies become more accessible, it is possible to incorporate machine learning algorithms to improve the process of analyzing such physiological data for important patterns in teachers' noticing behaviors.

Findings presented here provide important implications for teacher educators and other practitioners seeking to use 360-degree video or other forms of VR in their coursework and professional development. First, despite emerging evidence that simply viewing 360-degree video, instead of standard video, exposes PSTs to a wider variety of student actions (Author et al., 2021b; Walshe & Driver, 2019), the manner PSTs engage with 360-degree video can be specified further (Huang, Richter, et al., 2021). For example, PSTs viewing the video used in the present study could be provided a labeled map of the classroom (see Fig. 6) and told to pay attention to specific students at particular moments in the video (i.e., Students F & G at 2:04 to 2:40). Use of such detailed maps have proven useful for discussion of 360-degree video by others when focusing on facilitating discussion surrounding students' content-specific actions (Author et al., 2020c).

7. Limitations

There are several limitations to the current study which we discuss to aid the reader in appropriately interpreting our findings, and in hopes to aid scholars in improving upon our approach. First, our sample size is limited to 44 participants in one teacher education program. Future study would benefit from a larger sample from more diverse settings and more diverse experiences amongst participants. As informative as the findings are, themes observed in the current sample are likely limited due to the sample itself. Corresponding to limitations due to our sample, we also did not collect additional information that could better inform current findings. Namely, participants' content knowledge, pedagogical content knowledge, and various pedagogical beliefs were not collected. Prior field experience and education major were collected but weren't included in a statistical analysis due to the low sample size in certain majors.

An additional limitation lay in our approach to examining participants' FOV data. We acknowledge that this is one of many possible ways to approach analysis of participants' FOV data. Alternatively, viewing patterns could have focused on where PSTs' FOV was directed spatially in the room instead of whether the teacher was present within the FOV. Ideally, machine learning could be applied to such pattern detection in the future study of such data. Such an approach could allow for patterns to be more emergent than those detected by human coders. However, such technology was not available at the time of our analysis. Therefore, we incorporated the iterative analysis process described earlier in the paper.

8. Conclusion

Where teachers attend in professional noticing (van den Bogert et al., 2014; Dessus et al., 2016; Huang, Miller, et al., 2021), and how they describe such noticing (Author et al., 2021b; Barnhart & van Es, 2015; Jacobs et al., 2010) are connected through embodied experience. Findings presented here support and extend those of Huang, Richter, et al. (2021) in suggesting that teachers' FOV provides important data for both research and practice in teacher education. Thus, this study advances the field of VR in teacher education by empirically illustrating a relationship between FOV and written professional noticing. In the same manner, this study also advances the field of teacher education regarding the nature of professional noticing as embodied. Future work is needed to explore additional physiological data and provide additional empirical evidence for how teachers' FOV is related to their professional noticing, and the nuances of this relationship. Indeed, our findings point to a relevant role of 360-degree videos as instruments of inquiry for better supervising and expanding PSTs learning and expertise. The role of this technology with its immersive potential is well suited for enriching the concept of noticing itself, connecting future educators to the learning environments they are supposed to inhabit and lead.

Credit author statement

Karl W. Kosko: Writing – original draft; Formal analysis; Methodology; Investigation. Enrico Gandolfi: Writing – original draft; Formal analysis; Investigation. Jennifer Heisler: Writing – original draft; Formal analysis; Investigation.

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