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Professional noticing as student-centered: Pre-service teachers' attending to students' mathematics in 360 video

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Abstract

Teachers' professional noticing has been described as transitioning from descriptions of general pedagogy to analysis of students' mathematical procedures and conceptual reasoning. Such a shift is described as a transition towards more student-centered noticing. In the present study, we used screen recordings of pre-service teachers' (PSTs) 360 video viewing to examine the relationship between where and what PSTs' looked at and what they attended to in writing. Results and findings suggest that at key moments during the 360 video viewed, PSTs attending to students' fractions focus on students whereas their peers focusing on general pedagogy (i.e., group work) focus on the teacher.

Keywords: 360 video, immersive representations of practice, professional noticing, teacher noticing

INTRODUCTION

Professional teacher noticing involves "honing in on a key aspect of or instance that occurs during a lesson and engaging in reasoning to make sense of it" (Stockero & Rupnow, 2017). During mathematics lessons, more sophisticated noticing involves unpacking students' mathematical reasoning in detail (Jacobs et al., 2010; van Es et al., 2017), whereas less sophisticated noticing may focus on the teacher's actions or students' non-content related behaviors (Barnhart & van Es, 2015; Huang & Li, 2012). Emerging scholarship suggests that differences in content-specificity of teachers' noticing correspond with how and where teachers look when viewing a classroom scenario (Dessus et al., 2016; Huang et al., 2021a; Kosko et al., 2021b). Teachers with more specific descriptions of content focus on fewer students at a time, whereas teachers with less specific descriptions of content attempt to focus on multiple students simultaneously (Kosko et al., 2021b; Pouta et al., 2020). Yet, beyond the number of students and events that specificity of one's noticing involves, there is a need to understand the nature of events that teachers attend to in-the-moment and how such attending corresponds with content-specific noticing.

To study this phenomenon, we use 360 video to examine pre-service teachers' (PSTs) tacit choices of where and what to attend with a focus on how such choice informs their articulated professional noticing. Contrasting standard video, 360 video records omnidirectionally; allowing the viewer to orient the camera perspective and choose where to look within the classroom. This better approximates a teacher standing within a classroom and facilitates a sense of presence (Ferdig & Kosko, 2020; Walshe & Driver, 2019). Recording PSTs' viewing sessions in virtual reality environments, such as 360 video, provides useful data to examine their tacit choices of what, where, and when to look (Gold & Windscheid, 2020; Huang et al., 2021b; Kosko et al., 2021b). We used such data to examine the nature of PSTs' attending in relation to the specificity of students' mathematics described in their written noticing. Analysis of such data fulfilled the purpose of this paper, which is to examine the relationship between where PSTs chose to focus in a 360 video and the specificity of their descriptions of children's mathematics.

THEORETICAL FRAMEWORK

Professional Teacher Noticing

Professional teacher noticing is a form of situation awareness (Amador, 2016; Kosko et al., 2021b; Miller,

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Contribution to the literature

- Prior literature suggests more content-specific professional noticing stems from attending to students in viewing videos. Results from this study extend findings of prior literature with data from screen recordings of 360 video viewing.
- This paper incorporated a novel methodological approach by using 360 video to examine where and what teachers focused in their field of view (FOV).
- Results indicate that teachers with more student-centered noticing tend to more often position students, literally, in the center of their FOV. Such findings extend those of prior literature.

2011). Situation awareness involves perception of pertinent elements in an environment, interpreting what and how certain elements are relevant, and determining future actions based on such interpretation (Endsley, 2017). Within the teaching profession, the three elements described by Endsley (2017) have become more specific to the education context. For example, Jacobs et al. (2010) advocate for attending to children's reasoning, interpreting children's understanding, and deciding how to respond to such an interpretation. Barnhart and van Es (2015) describe *attending* to relevant classroom occurrences (i.e., students' thinking & learning), *analyzing* or interpreting those sense-making events, and *responding*; which refers to how pre-service teachers would use their attending and analyzing for logical next steps. van Es et al. (2017) noted that teachers may attend to various, interrelated facets. For example, in their *framework for noticing ambitious pedagogy*, van Es et al. (2017) distinguish between teachers attending to the mathematics of the lesson or students' mathematical thinking. Notably, most teachers who attended to students' mathematical thinking also attended to the mathematics of the lesson (van Es et al., 2017). For the purposes of the present study, we focus on attending to and interpreting students' mathematical thinking, while acknowledging other pedagogical events that can, and are, attended to by teachers (Kosko et al., 2022).

Professional noticing varies in degree of sophistication, with teachers initially attending to generic classroom events such as classroom management (behavior, seating arrangements) or the teachers' facilitation of the lesson (Barnhart & van Es, 2015; Jacobs et al., 2010; van Es et al., 2017). Through professional development or supportive experiences, teachers can learn to begin attending to students' mathematical procedures, in which they focus on whether certain procedures are enacted and if the child has found the correct, or expected result. A more sophisticated form of noticing involves attending to students' reasoning about the mathematical concept at-hand. In such instances, procedures may be referenced, but the focus is on students' strategies and evidence of how they reason about the content–not whether they found a correct response (Jacobs et al., 2010; van Es et al., 2017). As teachers learn to interpret events attended to and decide how to respond, they may initially only describe such events before beginning to make claims about why such events are important and use evidence to support such claims (Barnhart & van Es, 2015). Teachers' sophistication across the three actions that encompass noticing are facilitated by an increase in specificity of what and how they notice. For example, as teachers focus on more particular student actions, they begin to consider a wider range of students' strategies and conceptual reasonings about content. This wider range influences how teachers consider their choice of task (Empson et al., 2021; Jacobs et al., 2010). For example, Empson et al. (2021) observed how such consideration influenced teachers' choice of number when considering equal sharing story problems to pose to elementary students. Notable in Empson et al.'s (2021) analysis, and important for the context of this study, is the observation that such aspects of teacher noticing are

> "not learned and implemented in isolation from the institutional contexts in which teachers work" (p. 12).

Rather, how a teacher engages in professional noticing is facilitated through experiences with representations of practice and experiences in the classroom itself (Bastian et al., 2022; Huang & Li, 2012; Jacobs et al., 2010; Kosko et al., 2021b).

Professional Noticing as Embodied

As a form of situation awareness, professional noticing involves identifying (or attending to) key aspects within the "blooming, buzzing confusion of sensory data" (Sherin & Star, 2011, p. 69) in the classroom. Thus, "attending involves not only looking closely at some features…but also disregarding other aspects of that environment" (van Es & Sherin, 2021, p. 20). In a similar manner, Scheiner (2016) notes that attending involves "selecting stimuli perceived in a scene" (p. 231). The distinction between attending and perceiving is a fundamental feature of professional noticing. Yet, by marking this as a key distinction, various scholars note the importance of perception as facilitated through various physiological sources but seldom examine data related to such physiology. Consider the elementary teacher standing in a classroom on a hot spring afternoon. The building does not have air conditioning, and the children are noisily engaged in the

math activity. The teacher can look at one group of students while listening to another group behind them and briefly check in on another group in their peripheral vision. This teacher's professional noticing is mediated by what they can hear (directionally), what they see (visually), where they are positioned in the classroom (spatially), and even the heat of the classroom. We consider such sensory experiences to contribute to how the teacher's professional noticing is constructed, what we refer to as *embodied noticing*. The two key differences between what we refer to as embodied noticing and typical descriptions of professional noticing is an acknowledgement that noticing is informed and mediated by embodied experience and an effort to investigate one or more facets of such embodied experience as part of teachers' noticing. Such descriptions of professional noticing are an acknowledgement that noticing is informed and mediated by embodied experience, and an effort to investigate one or more facets of such embodied experience as part of teachers' noticing.

Evidence of embodied noticing can be found in various studies, including research using eye-tracking technology (Cortina et al., 2015; Dessus et al., 2016; Huang et al., 2021a; Lee & Tan, 2020; Stüermer et al., 2017; van den Bogert et al., 2014), and teachers' field of view (FOV) in virtual reality (Gold & Windscheid, 2020; Huang et al., 2021b; Kosko et al., 2021b, 2022). Such eye-tracking studies have used standard video recordings to examine differences in how teachers attend to classroom management events. For example, Cortina et al. (2015) and Huang et al. (2021a) both examined pairs of mentor (experienced) classroom teachers and their mentees (novice student teachers) using mobile eye-tracking glasses. Experienced teachers focused on a wider range of classroom management events in the classroom, but focused on students at a higher frequency and duration. By contrast, more novice teachers focused on events proximally closer to them and focused on students to a lesser degree than their mentors. This is a pattern evident in other eye-tracking studies of experienced and novice teachers (Dessus et al., 2016; Stüermer et al., 2017; van den Bogert et al., 2014). Essentially, experienced teachers may perceive more of what occurs in the classroom than less experienced teachers, but may also attend to more student-centric events (Pouta et al., 2020; Stahnke & Blömeke, 2021). Two key limitations are apparent in current eye-tracking literature: first, such scholarship includes only standard video, which limits analysis of how the body or head turns in the classroom, and of events that were *not* attended via eye-gaze; second, such scholarship focuses on the least sophisticated form of professional noticing described as 'generic' by Jacobs et al. (2010) and van Est et al. (2017).

Virtual reality (VR) has also been used to examine the embodied nature of professional noticing, with a specific focus on analyzing teachers' field of view, or FOV, while wearing a VR headset (Huang et al., 2021b; Kosko et al., 2021b) or viewing it on a flat screen (Kosko et al., 2021b, 2022). Huang et al. (2021b) examined PSTs' perception of classroom management events in a simulated VR-based classroom and found that a higher number of disruptive events decreased the likelihood PSTs would include such events in their FOV. Huang et al.'s (2021b) findings support prior conjectures (Cortina et al., 2015; Huang et al., 2021a) that a teachers' ability to process multiple events within a scenario interacts with their ability to notice key events. Comparing professional noticing of mathematics when PSTs viewed standard versus 360 videos, Kosko et al. (2021b) found that PSTs who watched the 360 video version of the same classroom scenario attended to more content-specific events in their written noticing than their peers who viewed the standard video version. Rather, differences were observed between the specificity of PSTs' professional noticing in viewing the standard video on a laptop, the 360 video on a laptop, and the 360 video with a VR headset. In a later study, Kosko et al. (2022) observed that PSTs who attended to the mathematics content with more specificity also tended to position students at the center of their FOV during recorded class discussions. By contrast, their peers positioned the teacher more often in the center of their FOV during the same portions of the lesson. Thus, PSTs who framed "students' voices as *literally* central" (Kosko et al., 2022, p. 27) in their FOV were the ones who generally attended to the content-based actions of those students. This particular finding supports and extends that of eye-tracking studies of teacher noticing (Pouta et al., 2020; Stahnke & Blömeke, 2021), but with more focus on content-specific actions, whereas most eye-tracking study of noticing is focused on classroom management. Although the emerging scholarship on using FOV from VR is promising, a key limitation to current research is that analysis of teachers' FOV is not as specific as eye-gaze data in certain regards. Interestingly, existing scholarship corroborates prior work for eye-tracking with standard video. Yet, it is important to note that in both areas of scholarship, there is a dearth of research. More scholarship is needed to better understand the nuances of how a teachers' FOV and eye-gaze (as well as various other physiological resources) interact with and inform their professional noticing.

In the preceding section, we described professional teacher noticing as something that develops from initially generic descriptions of general pedagogy to more specific interpretations of mathematics and students' mathematical thinking. The current section expanded on the notion of noticing as embodied activity by citing evidence from eye-tracking and VR-based studies. Although nascent as a body of literature, we believe such scholarship provides for a more nuanced understanding of professional noticing as a theoretical construct. Specifically, we conjecture that by physically

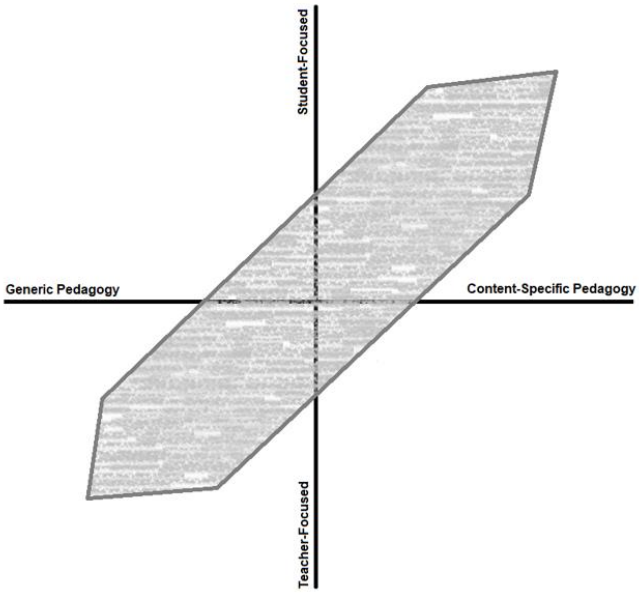


Figure 1. Hypothesized interaction between focus of attention and topic(s) attended in noticing

focusing on students in a mathematics lesson, teachers are more likely to attend to both the mathematics content and the students' reasoning surround that mathematics. This conjectured relationship is illustrated in **Figure 1** and supported by prior literature with VR-based representations (Gold & Windscheid, 2020; Huang et al., 2021b; Kosko et al., 2021b, 2022; Walshe & Driver, 2019), as well as literature with standard video-based experiences (Huang et al., 2021a; Mitchell & Marin, 2015; van Es et al., 2017). Specifically, teachers with less sophisticated noticing, as evidenced by spoken or written descriptions of key events, will tend to focus more on the teacher in-the-moment. By contrast, teachers with more sophisticated, specified noticing will tend to focus on students in-the-moment. Although we have cited prior literature as evidence to support this conjecture, there is a need for empirical evidence for it–thus, the purpose of the present study.

Summary

The use of video can help PSTs to refine their descriptions of students' actions to be more content-specific reflections that shift from more general to procedural, and then to conceptual descriptions of mathematics and students thinking (Barnhart & van Es, 2015). We argue that professional noticing is embodied, and that VR-based representations of practice, like 360 video, provide a more immersive experience to both study and facilitate PSTs' professional noticing (Huang et al., 2021b; Kosko et al., 2021a; Walshe & Driver, 2019). Such facilitation may occur through viewing 360 videos with VR headsets or on a flat screen device (Kosko et al., 2021b). Particularly, different scholars have begun to record where PSTs focus on VR (i.e., their FOV) and relate those perceiving behaviors to PSTs' pedagogical decisions and reasonings (Ferdig et al., 2020; Gold & Windscheid, 2020; Huang et al., 2021b). Examining where and how PSTs look *at* a scenario, such as with eye-tracking data with standard video (Huang et al., 2021a), is useful. However, examining where and how they look *within* a scenario provides an added dimension of data regarding PSTs' selective attention (Huang et al., 2021b). Despite the emerging field of literature related to embodied noticing, there is still a dearth of literature in the area. In particular, there are studies that examine embodied noticing from the perspective of whether teachers attend to more generic pedagogy, such as classroom management (Cortana et al., 2016; Desus et al., 2015; Huang et al., 2021a, 2021b) and there are studies that examine embodied noticing from the perspective of attending to students reasoning or the classroom content (Kosko et al., 2021b, 2022; Walshe & Driver, 2019). However, such scholarship either ignores students' reasoning and classroom content or deemphasizes the nuance associated with generic pedagogical events such as classroom management, facilitating groups, etc. The present study seeks to bridge this gap by examining the embodied noticing of both general and content-specific noticing. We believe there is a need for additional study on the embodied nature of more sophisticated, content-specific professional noticing, as well as more generic facets of pedagogy. We particularly were curious regarding similarities and differences in how such different forms of attending are conveyed by teachers' embodied actions. Therefore, the purpose of this paper is to examine the relationship between where PSTs chose to attend in a 360 video and the specificity of their descriptions of children's mathematics. We address this purpose with the following research questions:

1. What content-specific and generic pedagogical facets do PSTs attend to in their written noticing?
2. Where do PSTs focus their attention when viewing the 360 video?
3. How are PSTs' written attending and visual focus related?

METHODS

Sample and Procedure

Participants included 21 PSTs enrolled at a Midwestern U.S. teacher education institute in Spring 2020. Most participants identified as white (91.7%), and female (76.1%). After completing consent and basic demographic questions, participants engaged in a brief tutorial describing how to watch 360 videos on a laptop and how to screen record their 360 video viewing sessions. Analysis of participants' screen recordings enabled us to identify their FOV (Huang et al., 2021b), where FOV includes the *location* and *time* a viewer looked at a specific point.

After receiving instructions and viewing a tutorial on how to watch 360 video, PSTs watched a 360 video (5 minutes and 49 seconds) of fourth grade students reviewing equivalent fractions using fraction strips (https://youtu.be/TJ4g37HFVgM). Within the video, students were asked to use their fraction strips to find an equivalent fraction to 5/6. Midway through the video, the teacher engages students in a brief class discussion where two students describe not being able to reduce the fraction because 5 is a prime number. The teacher and students also note the relationship between finding equivalent fractions with the fraction strips and by finding a common denominator. Students are then asked to find an equivalent fraction to 3/8; purposefully chosen by the teacher since an equivalent fraction could not be modeled with the fraction strips. The video ends after a brief discussion of how students needed to find a common denominator using multiplication, instead of fraction strips, to find an equivalent fraction to 3/8. After viewing the 360 video, PSTs were asked to complete two written prompts based on their notes while viewing the video. First, they were asked to describe all pivotal moments they had noticed in their viewing (i.e., any moment you (PSTs) believe is important for the teaching and/or learning of mathematics). Next, PSTs watched the 360 video a second time, having selected one of their initially noted moments as the "most informative for them for teaching and/or learning of mathematics." PSTs were asked to describe it in further detail after watching the video a second time.

The 360 video used in this study was chosen for various reasons. First, the 360 video camera was positioned close to two tables where the viewer could observe students' use of the manipulatives and conversations with tablemates clearly at each table. The remainder of the classroom (two other tables and the teacher) were suitable for viewing for whole class discussions but one could not see the table work at the other two tables. The level of detail was similar to standing by two tables on one side of the classroom where you can see some, but not all of what takes place at the other side of the classroom. The content of the video was also a rationale for selection. First, fractions are an important topic in mathematics teacher education. Second, within the recorded video are many potentially salient moments for PSTs to attend. There is a class conversation, where students J and I discuss how prime numbers do not allow for reducing a fraction, as well as students C and A having the same conversation at another point in the video. There are conversations between various students (G & F, C & A) regarding how to find an equivalent fraction, what numbers to multiply, or how it relates to the fraction strips used. These and similar moments provide opportunities for PSTs to observe how children can reason about fractions both symbolically and visually, as well as why and how finding equivalent fractions symbolically relates to visual representations such as fraction strips. The video also included productive conversations due to the teacher's classroom management (i.e., facilitating group work). Thus, the 360 video provided various opportunities for PSTs to attend to mathematics, student thinking, and generic pedagogy; thereby providing an ideal representation for examining how PSTs' tacit choice of where to focus in the 360 video interacted with what they attended to in their writing.

Analysis

We used a convergent mixed methods research design to examine the interplay between PSTs' written professional noticing and their recorded focusing actions while viewing 360 videos. Creswell and Plano Clark (2018) describe convergent mixed methods designs as utilizing qualitative and quantitative methods to triangulate results surrounding the same phenomenon. In the current study, that phenomenon is PSTs' attending, with evidence of PSTs' attending stemming from their written descriptions of what they noticed and from recordings of their 360 viewing experiences. PSTs' writing was examined qualitatively using systemic functional linguistics (SFL) to examine the use of grammatical references to events and moments in the recorded scenario. PSTs' video recorded viewing sessions were quantitatively examined to assign a section, or region, of the classroom for each second of the video viewed. Data were then merged such that qualitative themes were quantized to allow for statistical analysis of how the presence of certain reference chains in PSTs' written noticings corresponded with where they attended in their viewing of the 360 video. We then examined trends observed in the merged data for key moments in the video. This involved reexamining PSTs' written reference chains in context with what and how they attended to specific portions of the video.

Figure 2 provides a visual illustration of this process, with further details of analysis in the sections that follow. Specifically, qualitative and quantitative analysis were considered as concurrent with equal weighting. Merging of data involved qualitative themes being quantized for Chi-square analysis, and using observed trends in the resultant quantitative analysis to re-examine segments of PSTs' viewing sessions to better understand the interplay between written noticing and recorded looking.

Qualitative Analysis of Written Noticing

We used SFL to examine PSTs' written noticing (Eggins, 2004). SFL is an approach to linguistics that examines how grammar functions to convey meaning. This method allows "the detailed and systematic description of language patterns" (Eggins, 2004, p. 21) and has been used by various scholars to examine the nuance of mathematics content conveyed in recorded

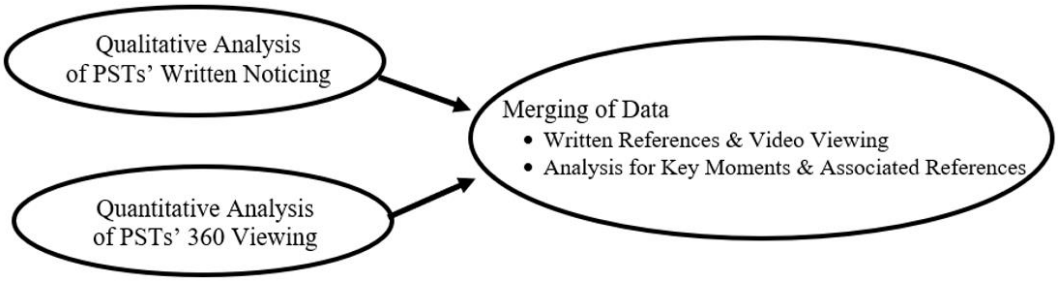


Figure 2. Overview of mixed methods design

classroom scenarios (González, 2015; Milewski et al., 2021). Specifically, we analyzed transitivity structures of PSTs' semantic clauses in order to identify reference chains. *Reference* refers to "how [grammatical] participants are introduced and 'managed' as the text unfolds" (Mehler & Clarke, 2002, p. 160). The repeated patterns of referencing builds reference chains, which can also convey how a particular referent is operationalized by an individual. Analysis of reference chains was considered essential for examining how written noticing corresponded with where and what PSTs focused in the video. Specifically, we considered the grammatical referents from PSTs' writing as potentially connecting to events that could serve as referents within their recorded 360 video viewing.

According to Eggins (2004), there are three elements of a clause that need to be identified in transitivity structure: the process, the participants, and the circumstance. For example, in analyzing the transitivity structure in one participant's written noticing shown below, the verbal groups (process type) are bold, the nominal groups (actors/participants) are underlined (mathematical nominal groups are distinguished using wave lines) and each clause is separated by //.

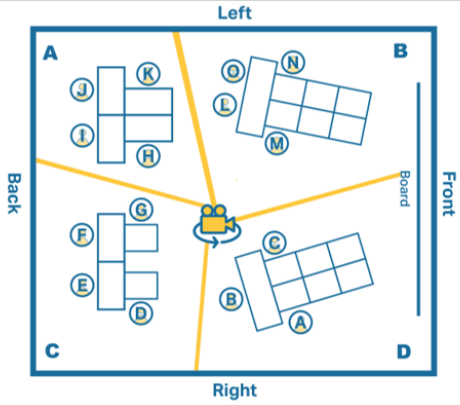
Teacher **collaboration** with students.//
She [teacher]**challenged** her student //
to **dig** deeper and
think outside the box
which *can* **be** very helpful
when **teaching** math.

The excerpt starts with the nominal element "teacher" which acts upon students though the transitive process "collaboration". The **collaboration** with students conveys a key aspect of this reference chain as the exchange of actions between teacher and students continues via different transitive processes: **challenging**, **dig** deeper, and **think**. Thus, this PST conveys a reference chain of the teacher scaffolding their students' engagement. Despite a reference that is specific to the content (i.e., math), this excerpt does not illustrate a reference chain that is specific to the content. Rather, there is little conveyance of how the content was experienced by this individual. Thus, analysis of reference chains allowed not only for identifying when specific aspects were referenced, but the relative emphasis placed upon those references (or the experience construed through reference chains).

After examining PSTs' written noticing using reference chains, seven themes emerged from the corpus including: teacher scaffolding, students' engagement (i.e., their observed thinking), hands on, sense language, fractions, group work, and 360 video. The current paper focuses on two themes: fractions and group work. Fractions was the focus of content in the 360 video. Also within the video, students were situated in groups, and this was the most common reference to general pedagogy amongst participants. Thus, these two themes seemed ideal for examining the conjecture illustrated in **Figure 2**. Analysis of reference chains was conducted by the second and third authors, with Cohen's kappa used to examine reliability of coding these themes. Both the fractions (K=.85) and group work (K=.59) reference chains were found to have sufficient reliability (Landis & Koch, 1977).

Quantitative Analysis of Video Viewing

The 360 camera was positioned between two group tables, with the other two group tables and front of the classroom in full view (see map in **Figure 1**). Following Kosko et al. (2021b), we partitioned the classroom map into four sections and coded each PSTs' viewing second-by-second for which quadrant of the classroom they positioned their FOV. Rather, each quadrant included one of the four tables in the classroom. Section B included one group, but also included the portion of the classroom where the teacher's station was and where she wrote on the board during class discussions. Unfortunately, we could not partition this latter area as a separate partition because it somewhat overlapped the table in section B given the camera placement. A total of 7,253 seconds of video viewing across 21 participants was examined. As shown in **Figure 1**, sections D (M=2 min 45 sec per participant) and B (M=1 min 49 sec per participant) included the largest portion of viewing times. There were a total of 92 seconds (M=4 sec per participant), where a specific section could not be identified, and this was primarily due to rapid movements of the camera perspective back-and-forth (i.e., the section viewed was classified as indeterminate). We used this data to merge with observed themes from participants' written noticings. Specifically, two Chi-



Section A	Section B	Section C	Section D	n/a	Total
462	2295	926	3478	92	7253

Figure 3. Classroom map with sections and descriptive statistics

Square statistics were calculated: one examined presence of attending to fractions with which section PSTs attended; the other examined presence of attending to group work with which section PSTs attended. This latter analysis is quantitative but also constitutes an aspect of merging the data (Creswell & Plano Clark, 2018). A Chi-square pair-wise post hoc analysis was then conducted using adjusted standardized residuals to identify specific comparisons between observed and expected counts. Specifically, a z-score is calculated to estimate whether, and in what direction, an observed count is statistically significant and different from one that was expected by chance. Given the nominal nature of the data (classroom quadrants and presence/absence of a theme), Chi-square and the described post hoc analysis were ideal for quantitative analysis.

Merging the Data

Analysis of merged data occurred in two ways. First, qualitative themes were quantized for Chi-square analysis (see prior section). This allowed for identifying larger patterns for further analysis. Thus, statistically significant variations in observed and expected viewing frequencies for certain sections allowed for a more fine-grained analysis of individual participants' viewing patterns in these particular sections. PSTs' written noticings and videos of their 360 viewing were then re-examined alongside each other at identified key moments in the recorded scenario.

FINDINGS AND RESULTS

Qualitative Findings of Written Noticing

A primary focus in analyzing PSTs' written noticing was to examine how and whether they attended to children's mathematics in the 360 video (i.e., fractions). This attending emerged as a theme, via PSTs' reference chains. Additionally, six other themes emerged from PSTs' written noticings. One of these themes, PSTs' attending to group work in the scenario, occurred more frequently and appeared to contrast the theme for attending to mathematics. Therefore, this qualitative analysis focuses specifically on these two themes (*fractions* & *group work)*[1] if the 11 PSTs (52%) attending to fractions and eight PSTs (38%) attending to group work, only one PST (4%) attended to both. There were also two PSTs (9%) who did not attend to either *fractions* or *group work*. This indicates the vast majority of participants either attended to the fractions or group work themes. **Figure 4** illustrates the excerpts from two PSTs' written noticing from these prevailing themes with coded reference chains.

As shown in **Figure 4**, the PST on the left uses the referent "equivalent fractions for 5/6 and 3/8" and constructs a reference chain by describing students' method of solving fractions using "fraction sticks" or "multiplication". The mathematical referent continues to evolve in the third sentence when "one group" explained "we could not divide the number 3… because it is a prime number". This reference chain clearly conveys a focus on equivalent fractions, which led us to identify it as the *fractions* theme. By contrast, the PST on the right used references incorporating a sequence of students' "collaboration" and "sharing". Specifically, the whole "class" is used as a primary participant (actors) of the text, which is conveyed transitively through collaboration and coming to a conclusion. Further, references to the "students" and "class" are contextual and reference occurrences in the recorded scenario that focus on group-based interactions. Thus, such reference chains emerged as a theme focusing on *group work*. Although most PSTs referenced either the fractions or group work themes, only one of the PSTs attended to both themes.

[1] The additional five themes are discussed in separate papers.

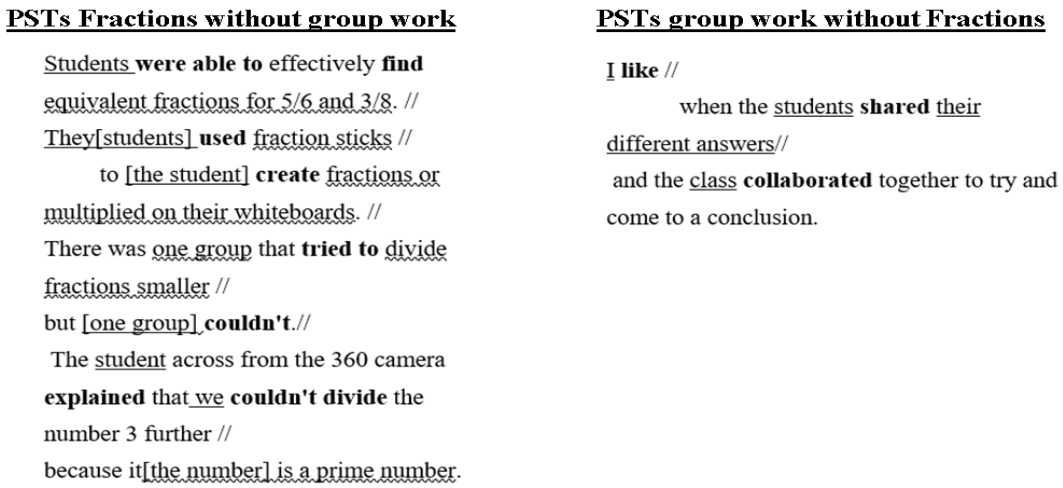


Figure 4. Example of PSTs fractions (left) & group work (right) (mathematical nominal group is distinguished using wave line)

One pivotal moment I noticed was at the beginning//
when the teacher **prompted** the students to work with a partner.
This is pivotal because//
It [working together] **allows** students **to share** their different ideas with each other and **work** together as well.
Another pivotal moment I **noticed** was when I **heard** //
many groups **saying** that they[students] **wanted to** multiply by two.
This is pivotal because it [multiply by two] shows that//
they[students] **know** how **to make** an equivalent fraction.
Another pivotal moment was when//
the teacher **asked** the students if //
they [students] **used** multiplication or fraction strips to get their answer. //
This [using multiplication or fraction strips] **shows** that//
the problem **is** a multiple ways multiple solutions task.

Figure 5. Example of both math-specific & group work emerged theme (mathematical nominal group is distinguished using wave line)

Figure 5 shows an excerpt of this PST's written noticing. The reference chains conveyed in **Figure 5** illustrate references to both fractions and group work. However, the PST appeared to use their references to fractions as a context for group work, rather than using group work as a context for describing students' work with fractions. Specifically, the PST introduced the referent "students working with a partner" and linked it to "share their ideas with each other" through the transitive process element, "sharing". Then in a subsequent clause, they introduced another referent "multiplying by two" linking it to "equivalent fractions." Yet, these mathematical referents actually extend from an earlier reference where the PST notes that groups shared "different ideas with each other." The concluding reference to a "multiple ways multiple solutions task" leaves some ambiguity as to whether the PST was primarily attending to the mathematics or the group work, but the primacy of group work earlier in the text suggests a leaning towards group work. Since the references to mathematics focus mainly on procedures (i.e., use of multiplication or fraction strips), there is reason to suggest it is what Barnhart and van Es (2015) describe as emerging from more general attending.

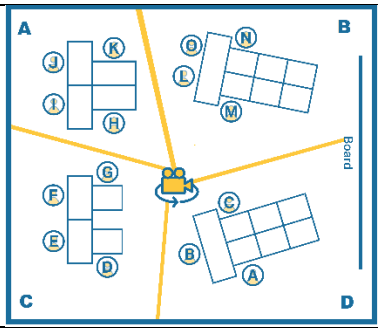
Quantitative Results of Where & What was Attended

We estimated a chi-square statistic to determine if where PSTs focused during the 360 video was independent from whether they attended to fractions in their written noticing[2]. Results indicated a statically significant chi-square statistic ($\chi^2(df=4)=35.85$, $p<.001$), suggesting PSTs' referencing of fractions in their written noticing and where they attended in the video were not independent from chance.

[2] Although it would be preferable to compare procedural and conceptual references to fractions, our sample size (n=21) required aggregation of data for the statistical analysis.

Table 1. Contingency table for PSTs' attending to fractions

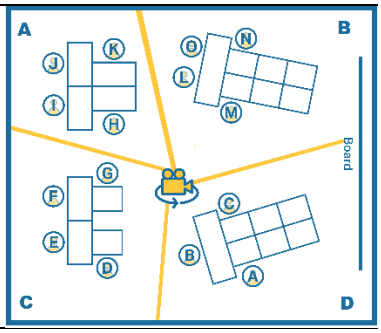
	Section				n/a*	Total
	A	B	C	D		
Not Attended	166 *219.88*	1157 *1,092.28*	460 *440.72*	1622 *1,655.32*	47 *43.79*	3,452
Attended	296 *242.12*	1,138 *1,202.72*	466 *485.28*	1,856 *1,822.68*	45 *48.21*	3,801
Total	462	2,295	926	3478	92	7,253



Note. *Indicates a region could not be identified (i.e., scanning or moving back-and-forth) & observed counts are in regular text and expected counts are in italics

Table 2. Contingency table for PSTs' attending to group work

	Section				n/a*	Total
	A	B	C	D		
Not Attended	265 *286.83*	1,359 *1,424.84*	507 *574.90*	2335 *2,159.30*	37 *57.12*	4,503
Attended	197 *175.17*	936 *870.16*	419 *351.10*	1143 *1,318.70*	55 *34.88*	2,750
Total	462	2,295	926	3,478	92	7,253



Note. *Indicates a region could not be identified (i.e., scanning or moving back-and-forth) & observed counts are in regular text and expected counts are in italics

To better understand this finding, we conducted a post hoc chi-square analysis using the adjusted standardized residuals for each cell in the contingency table (see **Table 1**). This allowed for more specific attention to where the statistically significant chi-square statistic stemmed. Post hoc analysis revealed that whether or not PSTs attended to fractions interacted with sections A (Z=±5.19) and B (Z=±3.27), with PSTs attending to fractions spending more time focusing on section A than expected by chance (M=+4.90 seconds per PST) and less time on section B than expected by chance (M=-3.27 seconds per PST).

Next, we estimated a Chi-square statistic to determine whether where PSTs focused during the 360 video was independent from whether they attended to group work in their written noticing. As with the prior theme, results indicated a statically significant chi-square statistic ($\chi^2(df=4)=89.95$, $p<.001$). Post hoc analysis indicated statistically significant differences between observed and expected counts (see **Table 2**).

This indicated that PSTs who attended to group work in their writing focused on section D less time than expected by chance (Z=-8.51), and focused on sections A (Z=2.16), B (Z=3.43), and C (Z=4.92) more than expected by chance. Additionally, PSTs who attended to group work in their writing tended to have more indeterminate coded portions of their viewing than was expected by chance (Z=4.35). For perspective, such differences equate to 21.96 seconds less time (per PST) than expected by chance for section D, and additional time focusing on sections A (M=2.73 s), B (M=8.23 s) and C (M=8.49 s) for each participant than was expected by chance. PSTs attending to group work were observed to have indeterminate viewing focus (i.e., rapid movement of their FOV) for an average of 6.88 seconds (2.52 s more than expected by chance), suggesting more variance in their viewing of the scenario.

Merged Results

The quantitative analysis used quantized codings from the qualitative analysis of PSTs' written noticings and suggested particular differences in where PSTs focused in the 360 video when accounting for what they attended to in writing. To better understand these patterns, we examined the timelines of where individual PSTs focused, grouping these PSTs by whether they attended to fractions or group work referents. By focusing on the results of the chi-square analyses, we were able to look for patterns related to an increased or decreased focus for specific regions. We then reviewed these PSTs' recorded sessions to assess these identified patterns.

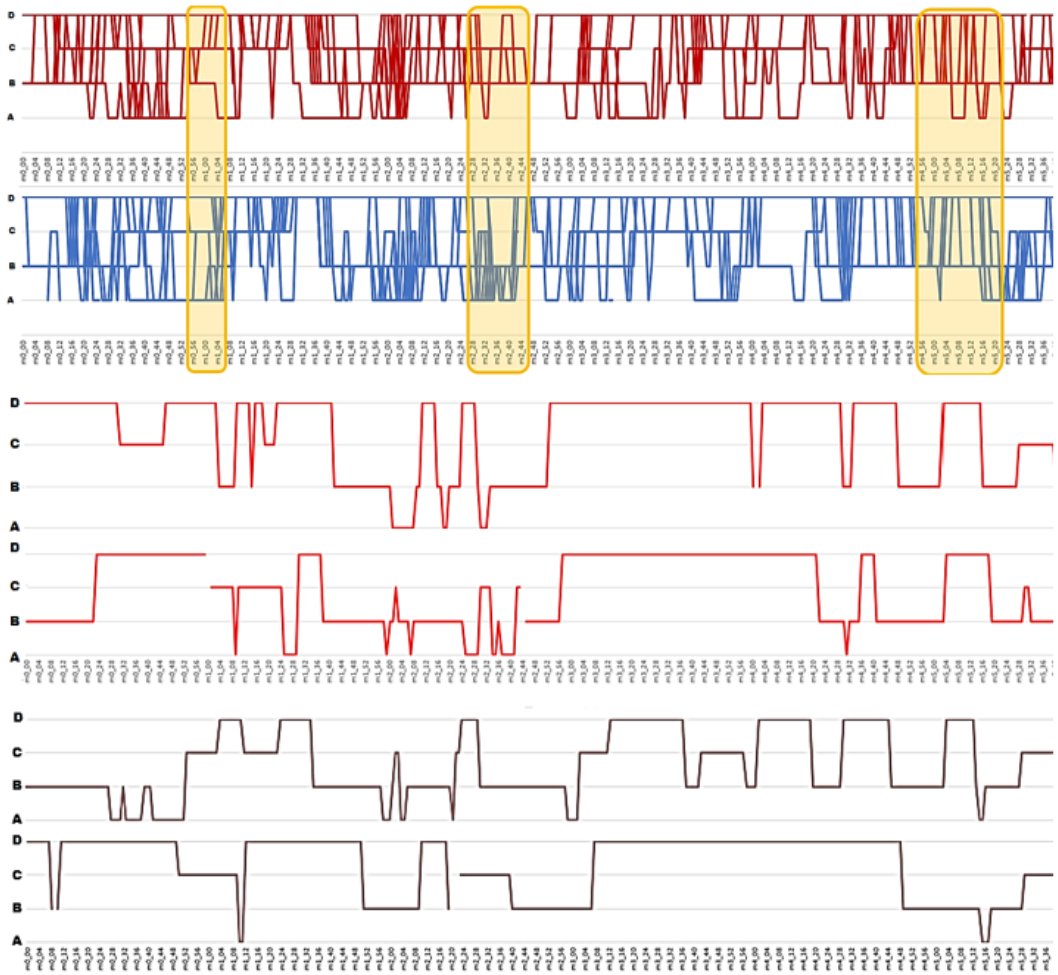


Figure 6. Participants' viewing by section & time [The top image is a composite comparing attending to math versus not attending to math. The middle and bottom images are examples of PSTs' viewing who attended to the mathematics (middle) or to group work (bottom)]

Figure 6 provides an illustrative snapshot of this process for the fractions theme. The top two graphs illustrate composites for PSTs who did not and who did attend to fractions in their writing. The bottom four graphs provide example graphs for participants at an individual level. By focusing on groups of individual graphs (attended to fractions only, group work only, both fractions & group work, or neither), we were able to identify three key segments in the 360 video that align with the patterns conveyed in the chi-square analysis.

The first episode of interest occurs from 0:56 to 1:04 in the 360 video. Within this brief episode, students are working on the first task in their small groups (i.e., finding an equivalent fraction to 5/6). At 0:56, the first author (who was observing the lesson) walks near the group table in section C and leaves at 1:04 to move toward section A. Examining recorded sessions, participants attending to group work turned their FOV towards the observer, with many shifting their FOV away from section C after they left (most often turning towards section D). By contrast, participants attending to the mathematics generally did not shift their perspective at this point. Some were already attending to students in section C, but more than half appeared to focus on section D. The PST attending to both group work and mathematics was focusing on section A at this timeframe where the teacher was talking with students at the table in that section.

The second episode of interest occurred between 2:28 and 2:48. This episode occurred during a brief whole class discussion following the first task. At around 2:28, the teacher was writing on the board (section B) and asking students in section A how they found an equivalent fraction to 5/6. The students noted that they initially tried to reduce the fraction but realized they could not "because 5 is a prime." This exchange, and the teacher's prompting for the justification was observed differently by participants who attended to group work and mathematics. With the exception of one participant (for a period of 1 second), those attending to group work did not look at students in section A. Their focus was on the teacher in section B. By contrast, participants attending to mathematics either focused predominately on the students in section A or engaged in a back-and-forth behavior of looking at the students in section A and the teacher in section B. Participants who attended to

neither group work nor mathematics focused predominately on section C, and the one participant attending to both attended to both section A and B, but moved their perspective so much that their 'focus FOV' was difficult to assess[3].

The last episode of interest occurred during the second whole class discussion of the 360 video between 4:56 and 5:20. Recall that for the second task the teacher asked students to find an equivalent fraction to 3/8. However, the fraction strips the teacher provided did not have 16ths (the smallest denominator was 12ths), as the teacher had purposefully provided a fraction that required an algorithmic strategy without telling the students. During the episode identified (4:56-5:20), the teacher solicited an explanation from a student at section D about how she found 6/16 as an equivalent fraction. Interestingly, participants who attended to group work and mathematics tended to focus initially on the teacher (section B), then the student (section D) and then the teacher again (section B). The notable difference is that participants attending to group work either shifted to the student in section D later, or turned back to the teacher sooner (or both). There was a subtle, but more prolonged focus on the student in section D amongst participants attending to mathematics (a few brief seconds more focus)[4].

Results from the chi-square analysis indicated that spending a few seconds more focusing in certain sections of the 360 video was associated with how participating PSTs attended to pedagogy. Supplemental analysis suggests that, at particular instances, PSTs attending to fractions focused on students where their peers attending to group work focused on the teacher. These differences are subtle on their surface, lasting but a few seconds in most instances. However, the statistical evidence suggests these observations are not trivial. We discuss the implications and limitations of these results and findings in the discussion.

DISCUSSION

The study described the relation between PSTs' choices of FOV and the specificity of their noticing the mathematics content of the lesson. Particularly, we focused on two themes that emerged in participating PSTs' written noticing: attending to group work and attending to mathematics specific to the recorded scenario (i.e., equivalent fractions). Whereas attending to group work has been associated with more generic, superficial noticing (Barnhart & van Es, 2015; Star & Strickland, 2008), attending to the content students engage is indicative of more sophisticated noticing (Barnhart & van Es, 2015; Jacobs et al., 2010; Kosko et al., 2021b). However, prior comparisons of more and less sophisticated noticing tend to group all referents of generic noticing together and do not consider themes within such a classification. By focusing on group work, particularly, we found that attending to generic and content-specific pedagogy were not always mutually exclusive. Although not discussed in depth in this paper, other themes referencing generic pedagogy emerged and co-occurred when PSTs attended to mathematics. For example, Heisler and Kosko (2021) compared student engagement (i.e., thinking) and teacher scaffolding and found that though the themes tended not to co-occur, there were instances where PSTs referenced both themes in their written noticing. Though focusing on different forms of reference, there appears to be consistency in that more generic pedagogy and more specific (either for student thinking or the mathematics they are learning) tend not to co-occur but can and do. This suggests a potential need for revision in various teacher noticing frameworks, as such frameworks are not explicit about such an overlap despite some reference to it in findings utilizing the framework (Jacobs et al., 2010; van Es et al., 2017). Given our findings, SFL may be a useful analytic tool for informing such work.

Our findings indicate approximately half of participants attended to fraction equivalence (the mathematics specific to the scenario), which echoes findings of other scholars studying PSTs (e.g., Jacobs et al., 2010). Similar to prior research (Star & Strickland, 2008; van Es et al., 2017) our findings suggest some PSTs used mathematics as a context for attending to group work, if noting the mathematics at all. However, following Wells (2017), many PSTs who attended to the lesson's mathematics in writing did focus on group work while viewing the 360 video. This provides support for an embodied interpretation of van Es and Sherin's (2021) description of attending as both selective as well as "disregarding other aspects" (p. 20) in the classroom. Indeed, such dis-attending is arguably prevalent in the data as illustrated in **Figure 6**. Rather, there may be more instances of *looking* at similar events, but some teachers *disattended* to elements that others *attended*, and vice versa. However, given the focus of our study, we are limited to conjecture regarding what teachers disattend. Future study should consider disattending explicitly, possibly through stimulated recall interviews with 360 video.

This paper reports on the use of 360 video and associated technological tools to examine PSTs' professional noticing. In doing so, aspects of embodied cognition are interwoven in our approach and explanation. Specifically, we draw attention to PSTs'

[3] This participant did not seem to focus in one place at this point. There were many *indeterminate* codes for them at this time period.

[4] The participant who attended to both group work and mathematics followed the pattern common amongst group work attenders here.

FOV, an embodied resource that is essential for teachers within the classroom. Our use of this tool adds to a growing body of literature incorporating FOV in the analytic toolkit of scholars studying professional noticing (Gold & Windsheid, 2020; Huang et al., 2021b; Kosko et al., 2021b, 2022). We suggest application of FOV is an extension of more traditional research on professional noticing. van Es et al. (2017) note that "the ways in which video can provide [visual] access to the teacher and the students in the classroom" (pp. 7-8) is of fundamental interest to their view of professional noticing. The teacher "standing or sitting in the classroom" (Sherin & Star, 2011, p. 69) selects certain elements somewhere around them. This may involve turning their head towards something and this turning of what is perceivable (visually) is what analysis of one's FOV provides. However, FOV does not capture all that is noticed by one's body. As noted by Sherin and Star (2011), teachers hear students at different points in the room. How sound is conveyed affects where PSTs adjust their FOV (Ferdig et al., 2020), and there are likely other facets related to teachers' embodied realities that interact with professional noticings. Thus, we note that as interesting and useful as we believe FOV to be in analysis of professional noticing, it is only one resource. Therefore, it is limited, and by consequence, the results reported here are limited to what PSTs were able to visually perceive of the recorded classroom–an aspect Kosko et al. (2021a, 2021b) refer to as a representation's *perceptual capacity*.

The present paper presents analysis of teachers' FOV in 360 video as a useful analytic tool for studying embodied noticing. However, pairing this approach with analyzing PSTs' written noticing through SFL is also important. Rather, by examining teachers' reference chains in their written noticing, we were able to re-examine data in the merging section to note whether and how these referents emerged. Key here was our focus on episodes that showed differences in looking behavior. References to group work in writing corresponded with looking more at a teacher whereas references to fractions corresponded with looking more at the student during these key episodes. What is less clear from our analysis is why these key episodes and no other parts of the 360 video? It is likely that the same phenomenon occurs when teachers view standard videos (certain episodes illustrate key differences in a recorded scenario), but using 360 video may make the issue more obvious.

There are several implications of this study for both research and practice. Regarding practice, findings presented here reinforce those common in the literature that suggest focusing on students' engagement with the content is important (Barnhart & van Es, 2015; Jacobs et al., 2010). Rather, by focusing on students in a recorded scenario, PSTs are more likely to focus on the lesson content more explicitly and in detail. Extending beyond this, when teacher educators engage PSTs' in viewing recorded scenarios (360 or standard video) including class discussions, they should encourage attention be given to what the *students* say and do in those discussions. By incorporating 360 videos of such scenarios, teacher educators can better assess whether PSTs look at students when they share their mathematical explanations, or if they focus on the teacher in such exchanges (Buchbinder et al., 2021; Walshe & Driver, 2019).

Results presented here support prior research suggesting an interaction between PSTs' FOV and attending to mathematics in a 360 video (Buchbinder et al., 2021; Kosko et al., 2022; Weston & Amador, 2021). However, there is a need for replication and extension. The present study included a limited sample size of 21 PSTs within a single institution. Larger sample sizes and additional contexts for participants (in-service or pre-service) should be considered in future research. Other scholars studying early childhood and elementary PSTs might consider using existing 360 videos (see https://xr.kent.edu for a library of such videos) or may choose to record their own videos and then record PSTs' viewing sessions either on a VR headset or laptop. Such procedures could replicate those described in the current paper, or could incorporate interviews, like stimulated recall, to examine other aspects of PSTs' in-the-moment focusing behavior. An additional area in need of further investigation is how PSTs' professional knowledge interacts with their recorded FOV behaviors–an area we did not examine in the present paper. There is evidence that teachers' content knowledge interacts with how they attend to events in standard videos (Dunekacke et al., 2015) and extending such scholarship seems a worthwhile area for future study. Lastly, the present study focused on a particular population (PSTs) using a specific embodied resource (their FOV). Further research is needed to understand in-service teachers' professional noticing in such scenarios (VR), and additional research is needed to study how teachers' various senses (sight, sound, touch) interact with their embodied professional noticing.

CONCLUSION

PSTs' selective attention as well as their reflection on what they attend are important elements of professional noticing (Sherin, 2007). Using 360 videos allowed us to understand how PSTs' FOV interacted with their written noticing. The findings suggest that PSTs' who attend to the content in the recorded scenario focus on students during key episodes of that scenario, whereas PSTs attending to more general pedagogy (i.e., group work) focus on the teacher in such episodes. However, by attempting to attend to both general and content-specific aspects, PSTs may demonstrate a more erratic FOV in viewing a classroom scenario. Additional study is needed, but the findings presented here support and

extend prior scholars' contention that attending to mathematics is a student-centered form of noticing (Jacobs et al., 2010; Kosko et al., 2022; van Es et al., 2017), and that noticing itself is embodied activity (Kosko et al., 2021a, 2021b, 2022; Walshe & Driver, 2019).

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Declaration of interest: No conflict of interest is declared by authors.

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