Mathematics Teacher Education and Development 2021, 23.4, 162-181

360 Video as an Immersive Representation of Practice: Interactions between Reported Benefits and Teacher Noticing

Karl Kosko
Kent State University

Tracy Weston
Middlebury College

Julie Amador
University of Idaho

Received: November 2020 Accepted: July 7 2021

This study examined and compared teachers' perceived affordances of 360 video as a representation of practice and their professional noticing of students' mathematics in 360 videos. Data were collected from both preservice and inservice teachers (n = 34) enrolled in one of three mathematics pedagogy courses. Data included participant responses after watching a 360 video of a primary grades mathematics lesson on the commutative property. Teachers described an important student action and indicated where they focused while watching the video. Findings indicate participating teachers considered 360 videos to be useful in facilitating attending to students' mathematics and adjusting the camera perspective were beneficial. Results from this study suggest that referencing teacher movement and student tables or groups is associated with a higher focus on student actions and that 360 video affords opportunities for teachers to notice students' mathematical thinking.

Keywords · preservice teachers · professional teacher noticing · 360 video · representations of practice · fractions.

Introduction

Representations of teaching and learning are prevalent in mathematics teacher education. In teacher education courses, representations typically include videos (Gaudin & Chaliès, 2015; Jacobs et al., 2010; Tyminski et al., in press), comics and animations (Friesen & Kuntz, 2018; Weston et al., 2018), and written vignettes (Lee & Ginsburg, 2007). As noted by Grossman et al. (2009), the viability of a representation of practice in teacher education is its capacity to provide a realistic representation of a classroom scenario. Although each of the aforementioned representation mediums has been found useful and effective, each limits what is perceivable to the teachers engaging with that representation (Kosko et al., 2021). By contrast, a relatively new medium for teacher education, 360 video, records a classroom scenario in a spherical direction. This provides the viewer with the autonomy to choose where to attend or focus in the recorded classroom (Walshe & Driver, 2019). On a flat screen, viewers do this by clicking and "dragging" the screen to "turn" to view the area they want to see. Although 360 video has its own limitations, such as the inability to move to any position in the classroom, the technology presents representations for teacher learning that provide affordances not possible with typical video (Roche & Gal-Petitfaux, 2017).

Given its newness, relatively little study of 360 video technology in teacher education has occurred. Early work by scholars outside of mathematics education suggested that preservice teachers valued engaging with the technology (Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019). A common observation in such early work was that preservice teachers valued the ability to look in any direction and find the affordance to be particularly helpful to view specific aspects of a classroom (Balzaretti et al., 2019; Roche & Gal-Petitfaux, 2017). According to research on teacher noticing (i.e., Jacobs et al., 2010; Mason, 2011; van Es & Sherin, 2008) the ability to perceive occurrences within a classroom, attend to those occurrences, and then interpret them is a key tenet of effective mathematics instruction. Examining the 360 video technology from the perspective of teacher noticing, Kosko et al. (2021) observed that preservice teachers who used 360 video noticed more student actions with increased mathematical specificity as compared to watching the same scenario with a standard video.

The emerging body of literature on 360 video suggests that inservice and preservice teachers value 360 video and that it may afford features that could be considered more effective than standard video for teacher preparation and education. Although such evidence is encouraging, we recognise there is a long history of promising new technologies that never met their prophesied potential. Too often, the excitement and anticipated value of a novel technology, or the single study demonstrating some beneficial learning outcomes, is viewed as sufficient evidence for adopting the technology. Although we view such evidence as useful, we do not view it as necessarily sufficient, and contend that additional research is necessary to more fully explore the affordances of 360 video. In this paper, we seek to bridge the gap between teachers' (inservice and preservice) perceived valuing of 360 video and the nature of their professional noticing. We believe such an examination will aid the field in understanding the viability of 360 video as a technology for mathematics teacher education. Therefore, the purpose of this study is to examine and compare teachers' perceived affordances of 360 video as a representation of practice and their professional noticing of students' mathematics in 360 videos.

Theoretical Framework

Dimensions of Representations of Practice

Grossman et al. (2009) use the term *representation(s) of practice* to describe "the different ways that practice is represented in professional education and what these various representations make visible to novices" (p. 2058). As described earlier, these "different ways" can come in the form of different mediums (e.g., standard video, written cases, animations, comics, 360 video, virtual reality,). Herbst et al. (2011) introduced two dimensions to describe the differences between representations of practice beyond the medium they are embedded: temporality and individuality. The dimension of *temporality* "alludes to the sense to which a representation of teaching can more or less immerse the user in the timeline and cadence of actions" (Herbst et al., 2011, p. 94). A written case may have a lower degree of temporality in that it can slow the cadence of events by describing details and student background not typically available in video. By contrast a video may have a higher degree of temporality by representing the timing and cadence of educational practice more reliably. Each representation uses the dimension of temporality for a particular advantage. For example, Buchbinder et al. (2016) used comic-based representations with preservice teachers so that they could "control the temporality of events" (p. 226). Notably, a similar action could be taken when watching video, since a viewer can pause and replay a portion of a scenario. Such 'replaying' of events represents less temporality, since this is not possible in real-time interactions, but replaying video or animations can be very useful. Thus, having less or more temporality is a characteristic of a representation and not necessarily a disadvantage.

The second dimension described by Herbst et al. (2011) is individuality. *Individuality* is the capacity of a representation to convey the "uniqueness of settings and participants and hence a sense of the differences among settings and among participants" (Herbst et al., 2016, p. 82). A comic or animation can represent a higher degree of individuality than a written case, similar to that of video representations (Friesen & Kuntze, 2018). Studying how preservice teachers respond to depictions of students of colour, Clark et al. (2020) manipulated the individuality in comic-based representations to convey students with no obvious skin tone (all blue characters) versus students with different human skin tones. Thus, like temporality, conveying less or more individuality is a characteristic that is not necessarily an advantage nor disadvantage of that representation.

Kosko et al. (2021) proposed an additional dimension to describe representations of practice: perceptual capacity. *Perceptual capacity* refers to a representation's capacity to convey aspects perceivable by human experience. This may include a higher degree of what is visually perceivable in a spatial sense (i.e., ability to turn in different directions within 360 video), to hear the direction of sound as if in an actual classroom (i.e., ability to hear students on your perceptual left in your left ear and students on your perceptual right in your right ear), touch, smell, and so forth. For example, a written case may have a higher degree of perceptual capacity by describing the smell of the classroom, the feel of the manipulatives, and the heat and humidity due to lack of air conditioning on a warm day. A 360 video can convey spatial aspects of the classroom, with students working on multiple sides of the camera that the viewer may attend; thus turning one's perspective to the left, right, and so forth. In such examples, different representations convey varying degrees and forms of embodied human experience.

The three dimensions described above represent ordinal descriptors for representations of practice. Figure 1 illustrates the intersection of these ordinal dimensions in a manner that helps to differentiate between two or more representations. Such differentiation is not necessarily medium-based, but we conjecture that certain mediums may readily afford higher or lower degrees of each dimension. For example, a written case typically has lower temporality, but can be crafted to have higher perceptual capacity conveyed through written descriptions of embodied experiences (descriptions of touch, smell, etc.). A 360 video affords a higher degree of perceptual capacity through the spatial sense (i.e., turning of perspective) than a standard video, but will generally have a similar degree of individuality and temporality to a video of the same scenario.

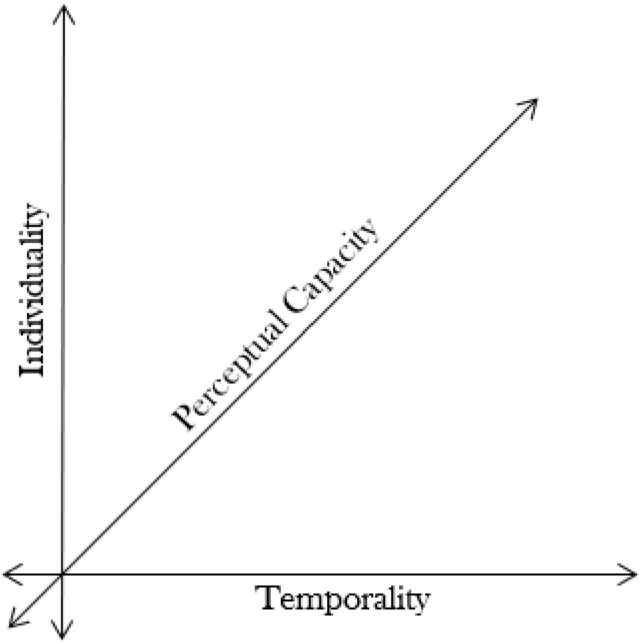

Figure 1. Ordinal dimensions of representations of practice.

Teacher Noticing as a Professional Skill

There is abundant evidence that noticing students' thinking is a professional skill that is not innate to mathematics educators or teachers (Huang & Li, 2012; Jacobs et al., 2010; Krull et al., 2007; Tyminski et al., in press). Several scholars have observed key differences between how preservice and inservice teachers attend to students' thinking. For example, Krull et al. (2007) observed that inservice teachers write more about students' actions than preservice teachers. Huang and Li (2012) similarly found that inservice teachers "are more sensitive to the student-centred teaching events, while novice [preservice] teachers, who may be struggling with effective guidance of students, paid close attention to that aspect" (p. 429). Furthermore, inservice teachers tended to notice substantive mathematical concepts and students' mathematical thinking more frequently than preservice teachers, "focusing on mathematical essence, rather than superficial aspects of guidance and management" (p. 430). Given the differences in noticing between preservice and inservice teachers, there is evidence that noticing can be developed and learned using appropriate tools, and 360 video may be one tool to facilitate these learning opportunities.

Jacobs et al. (2010) provided an additional perspective to understand the development of professional noticing. Noting that being an inservice teacher does not automatically lead to increased noticing, Jacobs et al. (2010) observed that as teachers gained more experience, they were more likely to describe specific student mathematical actions and strategies. Yet, such experience may involve more than spending more years in the classroom, or increased levels of expertise (Mason, 2002). Examining preservice teachers' professional noticing when involved in lesson study, Amador and Weiland (2015) found that preservice teachers attended to students' mathematical reasoning more so than some cooperating inservice teachers and university supervisors viewing the same videos. Seidel et al. (2011) compared the teacher noticing of inservice teachers with or without experience in analysing video of classroom instruction. Similar to Jacobs et al. (2010), Seidel et al. (2011) found that those inservice teachers with experience in viewing video of classroom instruction demonstrated more sophisticated professional noticing than their inexperienced counterparts. Rather than suggesting technological proficiency, the aforementioned findings suggest professional development should target professional noticing as a skill to be learned. The effectiveness of such targeted professional development is observable in the findings presented by Tyminski et al. (in press), who found that preservice teachers' proficiency in teacher noticing increased with time and experience; where experience involved both field experience in school settings and targeted professional development in teacher noticing.

Representations for Professional Noticing

Teacher noticing is a professional activity that can be developed through a combination of experience with students and professional development (Amador & Weiland, 2015; Jacobs et al., 2010; Tyminski et al., in press). Yet, the representations that teachers use to engage in professional noticing interact with how teachers notice (Friesen & Kuntze, 2018; Herbst et al., 2013; Kosko et al., 2021; Miller & Zhou, 2007; Seidel et al., 2011; Weston et al., 2018). Scholars studying the use of animations and comics have found that in certain contexts, differences in how the dimensions of individuality and/or temporality may or may not affect the specificity of mathematics attended to by teachers viewing the representations (Amador et al., in press; Friesen & Kuntze, 2018; Herbst et al., 2013). In the context of video, Miller and Zhou (2007) noted that the very act of producing the video of classroom practice directly affects what is represented. "What makes video cases compelling is their ability, partly real and partly illusory, to communicate to viewers something of the chaos and complexity of classroom interactions" (p. 332). Factors that can affect how compelling such video cases are include the placement of the camera, the length of the recording, and when or how to position the mathematics taking place in the video, as well as video complexity (Superfine & Bragelman, 2018; van Es et al., 2015). Earlier in this paper, we suggested that the perceptual capacity of video also matters; a factor we consider in exploring the affordances of 360 video for facilitating professional noticing.

Researchers examining use of 360 video in teacher education have found that preservice teachers note the benefit of moving the camera perspective in any direction (Kosko et al., 2021; Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019). Walshe and Driver (2019) noted an increased sense of presence in the recorded classroom, which they suggested "develops a more nuanced understanding of [preservice teachers'] microteaching, and supports their self-efficacy" (p. 103). Similarly, Roche and Gal-Petitfaux (2017) noted that the ability for preservice teachers to 'move' in the video allowed them "to understand the context" of the classroom and improve their ability to "focus on each student engaged" in the lesson (p. 3423). Expanding on this literature, Kosko et al. (2021) compared preservice teachers' viewing of a standard and 360 video of the same classroom scenario. They found that preservice teachers who viewed the 360 video attended to more student mathematical actions and were more likely to describe reform-oriented pedagogy.

Kosko et al. (2021), suggested the increased description of substantive mathematics and student actions was likely due to 360 video allowing for more students' actions to be perceivable (i.e., more students could be attended to in 360 video, and therefore were attended to more). This aligns with findings presented by both Roche and Gal-Petitfaux (2017) and Walshe and Driver (2019).

Zolfaghari et al., (2020) examined the use of multi-perspective 360 video in teacher education, meaning there are multiple 360 video cameras recording in a classroom at the same time. Preservice teachers viewed a representation that allowed them to switch between one of three synchronised 360 videos of the same scenario; allowing them to 'move' from one point to another in the recorded classroom. Key to the current paper is the finding by Zolfaghari et al. (2020) that when given the choice to rewatch the video a second time and focus on students' mathematics at one of four tables, nearly half of preservice teachers focused on the same table (and the same specific student at that table). This suggests that although 360 video allows preservice teachers to attend to more students' mathematical actions (Kosko et al., 2021), when asked to focus on fewer students, preservice teachers viewing 360 videos can focus on the same set of students and actions. 360 video allows for a more immersive representation that more closely approximates the messy interaction of a classroom (Walshe & Driver, 2019). Yet, evidence from the emerging literature suggests that it can be used as a means to focus teachers' attention on more specific and substantive student actions. As promising as this emergent literature is, there is a risk of the novelty of the technology (360 video) affecting how teachers engage with it, rather than the increased perceptual capacity. If the observed affordances of 360 video are merely due to affinity for the novelty of this technology, then mathematics teacher educators need not invest in creating and/or incorporating this new medium.

We conjecture that the increased perceptual capacity afforded by use of 360 video allows for a larger variety of student actions to be observed by teachers when viewing a classroom scenario. Given that this is an affordance numerous scholars have observed teachers describe (Kosko et al., 2021; Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019; Zolfaghari et al., 2020), we sought to understand what about this affordance that preservice and inservice teachers valued and how this related to their noticing of students' mathematics. Thus, the purpose of this study is to examine whether and how teachers' perceptions of what they were able to view related to what they attended to in their professional noticing of student mathematics. To fulfill this purpose, we sought to answer the following research questions:

- What affordances of 360 video do preservice and inservice teachers report, following use of the medium in a professional development setting?
- How do teachers' reported affordances of 360 video relate to aspects of their professional noticing?

Methods

Data were collected from students (n = 34) enrolled in one of three mathematics pedagogy courses, with each researcher teaching one of the courses within an education program at their U.S. based institution. All data were collected during the 2019-2020 academic year (August 2019 through May 2020). We were interested in the use of 360 video across a range of settings, and so the courses we selected for data collection have some differences with some participants including inservice teachers and others including preservice teachers working towards initial licensure. One course took place in Fall 2019 as an in-person, undergraduate, mathematics pedagogy course for preservice teachers leading to initial certification and focused on PreK through grade 3 (ages 3 to 9). The second course was a K-6 undergraduate mathematics pedagogy course (ages 5 to 12) for preservice teachers leading to initial certification. The course took place in Spring 2020 and was initially face-to-face, but transitioned to virtual delivery due to COVID-19. The third course was a graduate course in Curriculum and Instruction for licensed inservice teachers working on their Master's in Education. It occurred during Spring 2020 and was on-line for the entire semester.

Data Collection

Participants in all three courses were first-time users of 360 video. Participants were provided with the same tutorial for how to watch 360 video, which was a one-and-a-half-minute 360 video the three researchers made as an introduction for how to watch 360 videos (XRi, 2019a). The data collection task, which was about multiplication and division, took place before students read or learned about those topics in all three courses. Our data collection was not impacted by COVID-19, since we designed the task to be completed as a "homework" assignment that students did independently, outside of class. Rather, the assignment was designed as 'online' prior to the COVID-19 pandemic.

After watching and interacting with the 360 tutorial video, participants watched a seven-minute 360 video of a third grade class, taught by the first author (XRi, 2019b). The participants were directed to "use a mouse or touch the screen to move where the camera is pointed" as they viewed the video. In the video, the teacher provided a group of third graders with a task that informally introduced them to the concept of the Commutative Property of Multiplication through the use of Cuisenaire rods. Cuisenaire rods are color-coded length manipulatives (whites = 1cm, reds = 2cm, blacks = 7cm, browns = 8cm, etc.). Students were directed to use only one color of rod (one set length of rods) to cover a seven by eight array of one-centimetre dots. The majority of students either used eight black rods (7cm lengths) or seven brown rods (8cm lengths) before being directed to explore rather seven rods of 8cm would fit on top of eight rods of 7cm. The video ended with a class discussion surrounding this stacking activity and what it meant mathematically.

Figure 2 visually illustrates how participants were able to attend to students at more than one location in the classroom. For example, a teacher may look at one table to their left (viewpoint A), then turn to look at the table to their right (viewpoint B), or they may look at any location in the classroom by pivoting from the camera placement. In this manner, multiple students' actions were observable throughout the recorded scenario.

After watching the 360 video, participants answered questions about the device they used (laptop, computer, phone, or tablet) and whether or not it had a touch screen. They were also asked two questions about their noticing: "What did you notice about teaching and learning?" and "Describe an important student action or statement in the video. Why was that important?" Using a classroom map for reference, they also reported where they focused their attention the most in the video. Finally, they were asked about their perceptions of 360 video use: "Based on the features of the 360 video, what did you look at that you may otherwise not have been able to see or examine (if watching a standard video)?" Responses were collected using either Google Forms or Qualtrics, with identical wording used in both platforms.

Figure 2. Stretched image of the 360 video field of view (bottom) with two example camera perspectives indicated in boxes on screen (enlarged top left and right images).

After watching the 360 video, participants answered questions about the device they used (laptop, computer, phone, or tablet) and whether or not it had a touch screen. They were also asked two questions about their noticing: "What did you notice about teaching and learning?" and "Describe an important student action or statement in the video. Why was that important?" Using a classroom map for reference, they also reported where they focused their attention the most in the video. Finally, they were asked about their perceptions of 360 video use: "Based on the features of the 360 video, what did you look at that you may otherwise not have been able to see or examine (if watching a standard video)?" Responses were collected using either Google Forms or Qualtrics, with identical wording used in both platforms.

Analysis

360 Affordances

Participant responses to the prompt, "Based on the features of the 360 video, what did you look at that you may otherwise not have been able to see or examine (if watching a standard video)?" were coded using a codebook specifically designed for this study, based on an initial round of open coding for themes. To create the codebook, two researchers initially reviewed a subset of data and wrote open codes based on the responses (Corbin & Strauss, 2014). The two researchers then met to reconcile codes and arrive at a consensus on relevant codes, which resulted in a codebook for Affordances of 360 Video. Table 1 includes the codes with definitions.

Table 1
Codebook for Affordances of 360 Video

Code	Definition and *Examples*
Teacher Referenced	Explicit mention of the teacher: *"I was also given the option to focus on the teacher"*
Teacher Writing on Board	Explicit mention of or reference to the "teacher writing"; does not apply to other teacher actions or mention of teacher: *"I was still able to look at what the teacher was writing on the board if I needed to"*
Teacher Moves Around	Explicit reference of: (a) teacher moving around classroom, or (b) teacher 'going' from one table to another (student-to-student): *"I was able to watch the teacher walk around the room and interact with the students"*
Student Referenced	Explicit mention of a student or students: *"I was able to look at several different children"*
Student(s) Manipulative(s)	Explicit mention of seeing manipulatives: *"I was also able to see what the students were doing and how they were using their manipulatives"*
Student Expressions	Explicit mention of student facial expressions: *"I could see on the students' faces when they were confused, thinking critically, or excited to share their answer"*
Student Verbal	Explicit mention about something student said aloud: *"Turning video to focus on students that are answering a question or explaining the strategy they use "*
Camera Perspective	Explicit or implicit statement about changes in perspective because of the camera: *"I was able to move the camera to where I wanted to focus"*

Different Tables / Groups	Explicit mention of a focus on different tables or groups (but specific groups, not "the whole class"): *"In the 360 video I was able to specifically focus on certain tables and students"*

Following creation of the codebook, three researchers independently analysed a subset of data and met to reconcile differences and discuss code application. Following that conversation, two researchers independently coded the entire data set with the agreed upon codes and definitions. Kappa was calculated for each code, which indicated good to excellent reliability (Landis & Koch, 1977). Kappas for each code, statistically significant at $p < .001$ unless noted, were: Teacher Referenced (K = .93); Teacher Writing on Board (K = .63); Teacher Moves Around (K = .72); Student Reference (K = 1.00); Student Manipulatives (K = 1.00); Student Expressions (K=.87); Student Verbal (K = .84); Camera Perspective (K = .42, p = .006), and Different Tables (K = .45, p = .010). After calculating Kappa, the two researchers met and reconciled all differences in codes.

After data were analysed in response to the question about the affordances of 360 video, an additional data set, from the original data collection, was analysed to understand the extent to which participants conveyed recognition of the commutative property in the video. For this analysis, responses from each participant for two questions were analysed collectively. Questions included, "What did you notice about teaching and learning?" and "Describe an important student action or statement in the video. Why was that important?" Two researchers each independently coded all responses based on the extent to which the participants conveyed recognition of aspects of commutativity in their response to either of the two questions. Table 2 includes the codes used for this analysis, along with a description for each code.

Table 2
Codes to determine explicit mention of commutative property.

Code	Definition and *Example*
Explicitly Conveyed	Explicit mention of the property by name "commutative property"; indication of some abstraction from a specific instance to a generalizable property: *"One student said the rods fit because they created an array of 7x8. Another student added on to that by saying the numbers were the same. This is important because it shows that the students know to use arrays and the commutative property of multiplication."*
Implicitly Conveyed	States 7 x 8 is the same as 8 x 7; indication of some abstraction from the concrete representation: *"Student on video: "They're both 7x8 or 8x7." This is important because it shows that the student understands that the factors in a multiplication problem can be flipped, and the product is the same.*

Tacitly Conveyed	Describes "stacking" the rods or that 7 brown rods is the same as 8 black rods; indicates the concrete representation of the property without specifying it numerically or symbolically: *"When one student gave the number of black and brown rods and said they were the same as the red rods. I think that was important because she making the connection that the numbers were the same by using the manipulatives and visually checking her work."*
Not Conveyed	Not mentioned explicitly, implicitly, or tacitly; may mention use the rods and different strategies, but no mention of equivalence: *"I noticed that the students shared the materials well and didn't seem to argue over using the same bin of rods. This is important because it allows the lesson to go smoother."*

For each participant, the most explicit code possible was the code assigned for analysis. For example, if a participant *tacitly* mentioned commutativity when asked what they noticed (first question) and then *explicitly* mentioned the commutative property when answer the second question about an important student action or statement, they received the code of "explicitly conveyed" because they demonstrated the capability of reaching that code in their response. This is similar to coding processes other researchers have used (e.g. Jacobs et al., 2010) to identify the highest level of reported capability within an activity. After independent coding from two researchers, Kappa to determine the explicit mention of the commutative property was calculated at (K=.88), indicating strong agreement. The two researchers then met to reconcile differences in codes and arrived at consensus codes commutative property for each participant.

Self-Reported Focus in Viewing

To better understand participants' focus while viewing the 360 video, they were asked to indicate up to a maximum of 10 locations in the classroom where they "focused their attention" while they watched the 360 video. Participants responded with a wide range (2 to 10) with an average of 8.66 points attended (SD = 2.38). Specified points of focus were grouped by region (see Figure 3) with student and tables grouped into one of four locations, and all other points of interest denoted as "teacher tracking." It is important to note that teacher tracking points of focus indicated participants reported noticing of the teacher at different points in the classroom and at different times. Notably, participants during class discussions (which took place after their individual data collection was complete) generally indicated these locations as places where the classroom teacher did something significant during the course of the lesson. Across all noted points of focus, 7.6% focused on the back left, 24.8% on the front left, 17.5% on the back right, 29.4% on the front right, and 20.8% on 'teacher tracking locations (i.e., the teacher at multiple points during the lesson). This distribution of responses was analysed in context with whether certain themes emerged using Chi-Square statistics. Thus, self-reported affordances of the 360 video were examined in context with where participating teachers indicated they focused during the lesson.

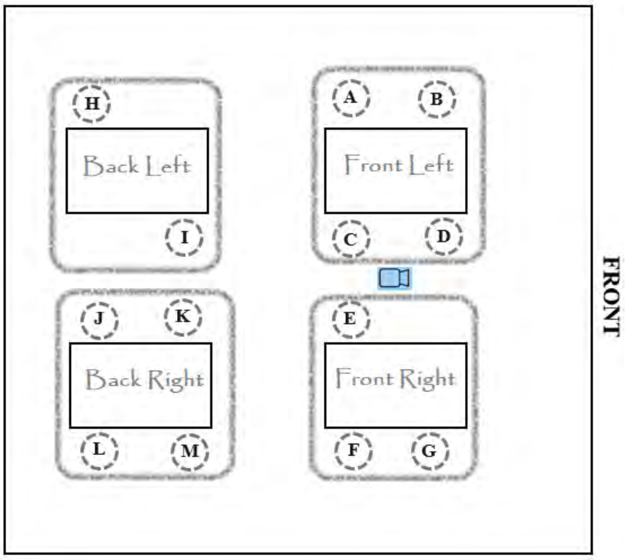

Figure 3. Classroom map of the recorded lesson with 360 video camera indicated.

Findings and Results

Emergent Themes

All but one participating teacher indicated the ability to look at and attend students was a benefit of 360 video (97.1%). As an example, one participant wrote:

> Based on the features of this 360 video, I was able to see the students work at all the tables instead of focusing on one student or focusing only on the teacher's instruction. I really liked that I was able to get a view of the whole classroom and all of the students.

Many participants indicated that seeing the teacher (67.7%) or adjusting the camera perspective (67.7%) was a benefit of the medium. As an example of both of these codes, one participant wrote:

> In the 360 video I was able to specifically focus on certain tables and students, and move the camera to where I wanted to focus, and I was still able to look at what the teacher was writing on the board if I needed to.

In this example, the prospective teacher highlighted the ability to move the camera and still focus on the teacher. Such findings confirm those of prior research, and emphasise the relative importance of participants being able to see students. Examining the more specified themes, the ability to see student work at different tables or in different groups (31.4%) and observing the teacher move about the classroom (22.9%) were the next-most prevalent themes. One participant wrote:

> I was able to watch different students working on the task that I otherwise would not have been able to. I was also able to follow the teacher as he was walking around the room which I would not have been able to do in a standard video.

Other themes that emerged were less prevalent with five or fewer participants noting them (Student Expressions = 11.4%; Student Verbal = 11.4%; Teacher Writes on Board = 5.71%). A summary of the prevalence of these themes is illustrated in Figure 4.

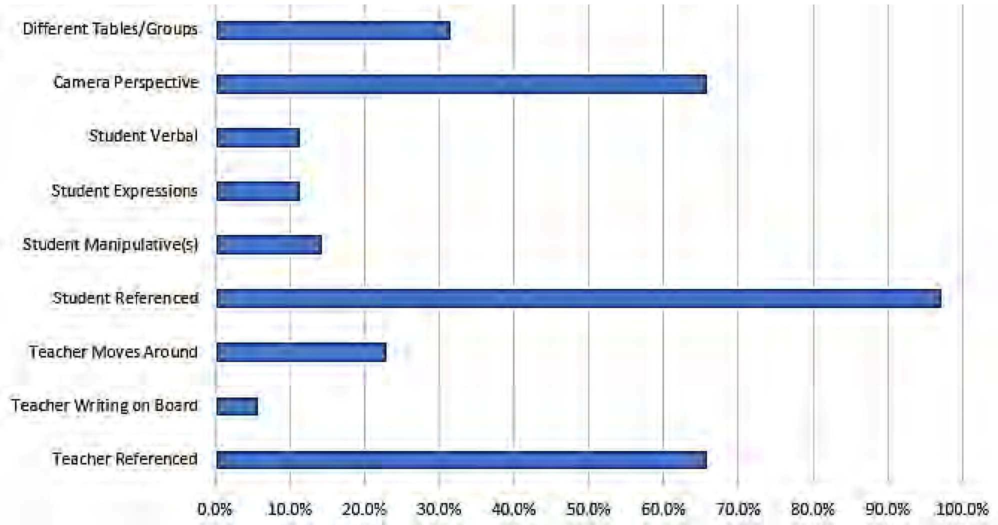

Figure 4. Affordances of 360 video noticed by participating teachers.

Analysis of participants' references to the Commutative Property revealed a relatively even distribution. Although most participants described the Commutative Property in some capacity (82.9%), a portion did not describe it at all (17.1%). Of those describing the Commutative Property, 31.4% did so *tacitly* by noting the stacking of the rods. This included phrases such as, "He realized by stacking the brown and black rods they were actually the same." The same proportion (31.4%) described the Commutative Property *implicitly* by identifying 7x8 as being the same as 8x7. For example, another participant wrote, "This student is recognising an important facet of multiplication: 7 by 8 is the same as 8 by 7." Finally, 20% *explicitly* identified the Commutative Property by naming the property in their writing, using language such as, "The student is modeling and explaining the Commutative Property of Multiplication, without knowing that the concept he is explaining is an official mathematical "property".

Affordances and Attending

Chi-Square analysis requires certain assumptions be met, which includes that the expected number of participant responses per cell be five or higher (McHugh, 2013). Given that certain themes for affordances did not meet this requirement, we limited our analysis of where participants reported they attended to the following four themes: teacher referenced, teacher movement, camera perspective, and different tables/groups. the overwhelming prevalence of participants who described seeing students as an affordance, and that described the Commutative Property in some capacity, limited our ability to analyse how such descriptions corresponded to their self-reported attending. Lastly, due to the number of Chi-Square statistics calculated (four), we used Simes p-value correction to avoid a Type I error (Simes, 1986).

Whether participants referenced the teacher in their description of affordances for the 360 video was independent of the frequency of where they reported attended in watching the 360 video ($\chi^2(df{=}4) = 1.61$, $p = .807$). Likewise, describing the ability to change camera perspective was independent of the frequency of where participants attended in the video ($\chi^2(df{=}4) = .521$, $p = .470$). No meaningful differences were observed between where participants reported they attended most in the 360 video and whether they conveyed these themes as an affordance of 360 video. By contrast, a statistically significant Chi-Square statistic was observed for the theme *teacher movement* and where participants reported they attended most ($\chi^2(df{=}4) = 10.70$, $p = .001$). Stated differently, certain observed tendencies were statistically different than what one would expect by normal probabilistic expectations. Table 3 illustrates this comparison with observed counts in regular text and expected counts by chance in italics. Comparing observed and expected counts, it is notable that participants who identified seeing the teacher move about the classroom as an affordance of 360 video tended to focus on the different tables more than expected by chance. These same individuals tended to report focusing on areas of the classroom where the teacher was located (elsewhere) than expected by chance. Although perhaps seemingly counterintuitive, this finding corresponds with observations by Kosko et al., (in review) where participants' recordings of their 360 viewing showed that many participants would follow the teacher as a segue to attend to specific groups of students. Thus, observing teacher movement may have served as a scaffold for participants to focus more heavily on specific groups of students in the 360 video.

Table 3
Distribution of Participant-Reported Focusing and Attending to Teacher Movement

		Back Left	Front Left	Back Right	Front Right	Teacher Tracking	Total
Teacher Movement	Not Conveyed	4 *4.93*	15 *16.09*	6 *11.37*	17 *19.09*	23 *13.51*	65
	Conveyed	19 *18.07*	60 *58.91*	47 *41.63*	72 *69.91*	40 *49.49*	238
Total		23	75	53	89	63	303

Note: Italicised numbers are those expected by chance and numbers in normal text are observed counts.

Participants' identifying seeing different tables/groups as an affordance of 360 video was independent of the frequency of where these participants reported they focused ($\chi^2(df=4) = 8.73$, $p = .003$). Participants who identified seeing tables/groups as an affordance of 360 video tended to focus on the teacher less than expected by chance, while those who did not identify this as a benefit of 360 focused to the teacher more frequently than expected by chance (see Table 4).

Table 4.
Distribution of Participant-Reported Focusing and Attending to Different Tables or Groups.

Different Tables/Groups		Back Left	Front Left	Back Right	Front Right	Teacher Tracking	Total
	Not Conveyed	17 *16.24*	54 *52.97*	30 *37.43*	59 *62.86*	54 *44.50*	214
	Conveyed	6 *6.76*	21 *22.03*	23 *15.57*	30 26.14	9 *18.50*	89
	Total	23	75	53	89	63	303

Note: Italicised numbers are those expected by chance and numbers in normal text are observed counts.

Discussion

The affordance of 360 video participants most frequently reported was the ability to visually see students (97.1%). Although this seems an obvious affordance of a whole-class video, some representations of practice do not have this capacity (i.e., written cases). Furthermore, many standard videos do not show students, or do not show them clearly enough to ascertain what they are doing or include enough detail for interpretations to be made about what they understand mathematically. This occurs when the video primarily focuses on the teacher, or only shows the back of students' heads because the camera is placed behind the students and points towards the front of the classroom. In this study, many participants described the ability not only to see students, but to observe more specific details such as reading writing on the whiteboard or seeing the way students arranged their manipulatives. This is similar to Cross et al.'s (2018) finding that 360 video allowed participants to see each child's engagement in recorded lessons, as well as Roch & Gal-Petitfaux's (2017) finding that using 360 video improved the viewer's ability to see what students were doing during the recorded lesson.

The vast majority of participants described the Commutative Property in some capacity (82.9%). The high prevalence of these two items co-existing (a focus on students and descriptions of the Commutative Property) supports Kosko et al.'s (2021) finding that use of 360 video can increase teachers' specificity when describing student mathematics. As teacher educators, we know that when we select videos with specific mathematical content in mind, it can often be "missed" by teachers – particularly many early stage preservice teachers. The fact that participants could see students doing mathematics and using the Commutative Property (for example, through the viewable use of manipulatives) is promising to us as teacher educators. Ironically, the high prevalence of attending to the Commutative Property in this study resulted in our own inability to calculate a Chi-Square statistic (a higher sample size may have yielded the minimum 10 participants needed for that category). As reported in previous studies, the perceptual capacity of 360 video is an important one for preservice teachers and a promising feature to us as teacher educators (Cross et al., 2018; Ferdig & Kosko, 2020; Gold & Windscheid, 2020; Roche & Gal-Petitfaux, 2017; Walshe & Driver, 2019).

Results from this study suggest that referencing teacher movement and student tables or groups is associated with a higher focus on student actions. Past literature indicates novice teachers are more likely to focus on the teacher in video recordings rather than students (Huang & Li, 2012; Jacobs et al., 2010). However, the 360 technology makes it possible for the viewer to "follow" the teacher as they move around the classroom, because no person ever moves off screen (Kosko et al., in review). Kosko et al. (2021) recorded preservice teachers' viewing of 360 videos and found that, at key moments, participants visually followed the classroom teacher, but once the teacher stopped moving to engage a group of students, the viewers focused their attention on that student group and their mathematics. Similarly, in the current study, both preservice teachers participating in class discussions reported that when they viewed the 360 video, at first they turned their screens to follow the teacher. Then, realising they would still hear the teacher even when he was not visible on screen, preservice teachers shifted their field of view to focus exclusively on the students. This phenomenon was not observed with inservice participants and may be due either to the lower sample size and/or inservice teachers' additional experience in the classroom. The recorded teacher was left "off screen" with preservice teachers turning their perspectives quickly to and away from the teacher as needed. This suggests that it may be possible to leverage novice teachers' gaze, using the teacher as a starting point and a "bridge" to student mathematical actions and understanding.

Inservice and preservice teachers reported that they could see more student actions in the 360 video than in a regular video, but still not as much as they wanted. For example, some recorded students were still obstructed by other students, or had their backs to the camera. Similar to standard video camera placement (van Es et al., 2015), this is an artifact of the room configuration coupled with the camera placement rather than the technology. If the camera is placed in the middle of table groups (see Figure 3), some students will have their backs to the camera, whereas if the camera is placed inside of a "U" shaped table arrangement, viewers' ability to see any student will be improved. Feurstein (2019) and Gold and Windscheid (2020) also noted that the position of the camera matters significantly, and Feurstein (2019) found that different camera positions were reported as useful by novice versus experienced business educators. Still, in any configuration, a limitation of single-camera 360 video recordings is that the viewer is "tethered" to the camera placement and can only turn their gaze from that fixed point, but cannot "walk" around the classroom or "zoom in" on desired locations. The use of multi-perspective 360 video (using multiple 360 cameras) "allows the viewers to watch different perspectives (cameras) of a scenario while switching their viewpoints" to "virtually move around a class, from one group to another" (Zolfaghari et al., 2020, p.317) . However, the learning curve for viewing multi-perspective 360 is higher than single-camera, and we recommend beginning 360 video use with a single camera perspective.

As stated earlier, we acknowledge the need for careful study before endorsing the adoption of new technology given all of the implications. At present, based on prior research and our own experiences using 360 videos in our courses, we find this representation of practice promising for several reasons. First, using 360 videos as a viewer is easy to learn for both preservice and inservice teachers and teacher educators. None of our students had used 360 video before this study, and they were all able to successfully use it within the time of a short (90 second) tutorial. Second, as described earlier in the paper, 360 video is more immersive and more similar to a real classroom than standard video (Cross et al., 2018; Ferdig & Kosko, 2020; Kosko et al., 2021; Walshe & Driver, 2019). This quality can be even further enhanced by viewing 360 videos using Virtual Reality headsets; although the associated learning curve and equipment needs will increase (Cross et al., 2018; Ferdig & Kosko, 2020; Kosko et al., 2021; Walshe & Driver, 2019). Part of the immersive nature of viewing 360 videos is due to the interactive experience for the viewer, since they manipulate their field of view. Choices for preservice and inservice teachers in viewing may approximate a real classroom in which the teacher needs to decide where to focus. Although somewhat dependent on the classroom layout and camera placement, 360 video can provide the viewer with the opportunity to observe more students doing mathematics and at the same time choose an individual or group to focus on. For example, Ferdig & Kosko (2020) found that preservice teachers wrote more about mathematics pedagogy when using 360 compared to standard video, and Kosko et al. (2021) found that preservice teachers' descriptions were more mathematically specific with 360 video use compared to standard video. Specifically, "preservice teachers using 360 video attended to more student actions in their written noticings, with more descriptive references to such actions than preservice teachers who viewed a standard video of the same scenario" (Kosko et al., 2021, p. 294).

Limitations for this study include our small sample size, which meant we could not examine all of the themes we found due to the resulting statistical constraints. However, we argue that conducting the study in three different contexts provides insight across a spectrum of teacher experiences that is helpful for understanding perspectives about 360 video. There are also other data sources that could be helpful for gathering information about 360 video use with teachers. For example, follow-up interview data could potentially provide more information about affordances and constraints of 360 technology and how this interacted with what participants chose to focus on. Other data such as screen recording or gaze (eye-tracking) technology could reduce reliance on self-report data.

Given the links between improvements in teacher noticing and student outcomes (Darling-Hammond, 2000; Sherin, Jacobs, & Philipp, 2011), we are interested in using representations to improve our preservice teachers' noticing. Perhaps as representations become closer approximations of actual teaching, they will provide improved scaffolding and opportunities to develop preservice teachers noticing through their use. If this is the case, it is important for teacher educators to continually evaluate, improve, and replace representations of practice as our options expand. We believe that 360 video merits the attention of mathematics teacher educators to further investigate its affordances and potential use in fostering teachers' professional growth.

References

Amador, J., Kosko, K. W., Estapa, A., & Weston, T. (in press). Prospective teachers' appraisals of technology platforms: Comparing perception and complexity. *Technology, Pedagogy, and Education*. https://doi.org/10.1007/s11528-020-00522-3

Amador, J., & Weiland, I. (2015). What preservice teachers and knowledgeable others professionally notice during lesson study. *The Teacher Educator*, *50*(2), 109-126. https://doi.org/10.1080/08878730.2015.1009221

Balzaretti, N., Ciani, A., Cutting, C., O'Keeffe, L., & White, B. (2019). Unpacking the potential of 360 degree video to support pre-service teacher development. Research on Education and Media, 11(1), 63-69. https://doi.org/10.2478/rem-2019-0009

Buchbinder, O., Zodik, I., Ron, G., & Cook, A. L. J. (2016). What can you infer from this example? Applications of online, rich-media tasks for enhancing pre-service teachers' knowledge of the roles of examples in proving. In A. Leuang & A. Baccaglini-Frank (Eds.), *Digital technologies in designing mathematics education tasks: Potential and pitfalls* (215-238). Springer. https://doi.org/10.1007/978-3-319-43423-0_11

Clark, L. O., Turner, B., & Lue, K. (2020). Preservice teachers' perceptions of depictions of mathematics teaching practice when enduring individual characteristics are introduced. In A. I. Sacristán, J. C. Cortés-Zavala, & P. M. Ruiz-Arias (Eds.), *Proceedings of the 42nd meeting of the Psychology of Mathematics Education of North America* (2037-2041). Cinevestav / AMIUTEM / PME-NA. https:/doi.org/10.51272/pmena.42.2020-341

Corbin, J., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. SAGE publications.

Cross, S., Wolfenden, F., & Adinolfi, L. (2018). *Transforming classroom observation and professional development with 360-degree video and mobile VR*. Presented at the 8th annual mEducation alliance symposium, Washington DC.

Darling-Hammond, L. (2000). Teacher quality and student achievement. *Education policy analysis archives*, *8*(1), 1-44. https://doi.org/10.14507/epaa.v8n1.2000

Ferdig, R. E., & Kosko, K. W. (2020). Implementing 360 video to increase immersion, perceptual capacity, and noticing. *TechTrends, 64*, 849-859. https://doi.org/10.1007/s11528-020-00522-3

Feurstein, M. S. (2019). Exploring the Use of 360-degree Video for Teacher-Training Reflection in Higher Education. In S. Schultz (Ed.), *Proceedings of DELFI Workshops 2019* (pp. 153=160. Gesellschaft für Informatik eVz. https://dx.doi.org/10.18420/delfi2019-ws-117

Friesen, M., & Kuntze, S. (2018). Competence assessment with representations of practice in text, comic and video format. In O. Buchbinder & S. Kuntze (Eds.), *Mathematics teachers engaging with representations of practice* (pp. 113-130). Springer. https://doi.org/10.1007/978-3-319-70594-1_7

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

Gold, B., & Windscheid, J. (2020). Observing 360-degree classroom videos: Effects of video type on presence, emotions, workload, classroom observations, and ratings of teaching quality. *Computers & Education, 156*, 1-13. https://doi.org/10.1016/j.compedu.2020.103960

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record, 111*(9), 2055-2100.

Herbst, P., Aaron, W., & Erickson, A. (2013). *How preservice teachers respond to representations of practice: A comparison of animations and video*. Paper presented at the 2013 Annual meeting of the American Educational Research Association, San Francisco, CA. http://hdl.handle.net/2027.42/97424

Herbst, P., Chazan, D., Chen, C. L., Chieu, V. M., & Weiss, M. (2011). Using comics-based representations of teaching, and technology, to bring practice to teacher education courses. *ZDM, 43*, 91-103. https://doi.org/10.1007/s11858-010-0290-5

Herbst, P., Chazan, D., Chieu, V. M., Milewski, A., Kosko, K. W., & Aaron, W. R. (2016). Technology-mediated mathematics teacher development: Research on digital pedagogies of practice. In *Handbook of research on transforming mathematics teacher education in the digital age* (pp. 78-106). IGI Global. https://doi.org/10.4018/978-1-5225-7305-0.ch010

Huang, R. & Li, Y. (2012). What matters most: A comparison of expert and novice teachers' noticing of mathematics classroom events. *School Science and Mathematics, 112*(7), 420–432. https://doi.org/10.1111/j.1949-8594.2012.00161.x

Jacobs, V. R., Lamb, L. L. C., & Philipp, R. A. (2010). Professional Noticing of Children's Mathematical Thinking, *Journal for Research in Mathematics Education*, *41*(2), 169-202. https://www.jstor.org/stable/20720130

Kosko, K. W., Ferdig, R. E., & Zolfaghari, M. (2021). Preservice teachers' professional noticing when viewing standard and 360 video. *Journal of Teacher Education, 72*(3), 284-297. https://doi.org/10.1177/0022487120939544

Kosko, K. W., Heisler, J., and Gandolfi, E. (in review). Using 360-degree video to explore teachers' professional noticing. *Computers and Education*.

Krull, E., Oras, K., & Sisask, S. (2007). Differences in teachers' comments on classroom events as indicators of their professional development. *Teaching and Teacher Education*, *23*(7), 1038–1050. https://doi.org/10.1016/j.tate.2006.02.001

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*, 159–174. https://doi.org/10.2307/2529310

Lee, J. S., & Ginsburg, H. P. (2007). What is appropriate mathematics education for four-year-olds? Pre-kindergarten teacher's beliefs. *Journal of Early Childhood Research, 5*(1), 2-31. https://doi.org/10.1177%2F1476718X07072149

Mason, J. (2002). *Researching your own practice: From noticing to reflection*. Routledge Falmer.

Mason, J. (2011). Noticing: Roots and branches. In M. G. Sherin, V. R. Jacobs, & R. A. Philipp (Eds.), *Mathematics teacher noticing: Seeing though teachers' eyes* (pp. 35-50). Routledge.

McHugh, M. L. (2013). The chi-square test of independence. *Biochemia Medica, 23*(2), 143-149. https://doi.org/10.11613/BM.2013.018

Miller, F., & Zhou, X. (2007). Learning from classroom video: What makes it compelling and what makes it hard. In R. Goldman, R. Pea, B. Barron, & S. J. Derry (Eds.), *Video research in the learning sciences* (pp. 321-334). Routledge.

Roche, L. & Gal-Petitfaux, N. (2017). Using 360° video in Physical Education Teacher Education. In P. Resta & S. Smith (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2017* (pp. 3420-3425). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE). https://www.learntechlib.org/primary/p/178219/

Seidel, T., Sturmer, K., Blomberg, G., Kobarg, M., & Scwindt, K. (2010). Teacher learning from analysis of videotaped classroom situations: Does it make a difference whether teachers observe their own teaching or that of others? *Teaching and Teacher Education, 27*, 259-267. https://doi.org/10.1016/j.tate.2010.08.009

Simes, R. J. (1986). An improved Bonferroni procedure for multiple tests of significance. *Biometrika, 73*(3), 751-754. https://doi.org/10.1093/biomet/73.3.751

Superfine, A., & Bragelman, J. (2018). Analyzing the impact of video representation complexity on preservice teacher noticing of children's thinking. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(11), 1-18. https://doi.org/10.29333/ejmste/99501

Tyminski, A. M., Simpson, A. J., Land, T. J., Drake, C., & Dede, E. (in press). Prospective elementary mathematics teachers' noticing of children's mathematics: A focus on extending moves. *Journal of Mathematics Teacher Education.* https://doi.org/10.1007/s10857-020-09472-2

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

van Es, E. A., Stockero, S. L., Sherin, M. G., Van Zoest, L. R., & Dyer, E. (2015). Making the most of teacher self-captured video. *Mathematics Teacher Educator, 4*(1), 6-19. https://doi.org/10.5951/mathteaceduc.4.1.0006

Walshe, N., & Driver, P. (2019). Developing reflective trainee teacher practice with 360-degree video. *Teaching and Teacher Education, 78*, 97-105. https://doi.org/10.1016/j.tate.2018.11.009

Weston, T. L., Kosko, K. W., Amador, J. M., & Estapa, A. T. (2018). Preservice teachers' questioning: Comparing platforms for practice-based teacher education. *Journal of Technology and Teacher Education, 26*(1), 149-172. https://www.learntechlib.org/p/181137/

XR Initiative at Kent State [XRi] (2019a, August 7). *Tutorial: How to Watch 360 Video* [Video]. YouTube. https://youtu.be/EKvm9cVo7qg

XR Initiative at Kent State [XRi] (2019b, July 17). *Grade 3 Commutative Property of Multiplication* [Video]. YouTube. https://youtu.be/ojhzS7n8ggo

Zolfaghari, M., Austin, C. K., Kosko, K. W., & Ferdig, R. E. (2020). Creating asynchronous virtual field experiences with 360 video. *Journal of Technology and Teacher Education, 28*(2), 315-320. https://www.learntechlib.org/p/216115/

Authors

Karl Wesley
Kent State University, USA
email: kkosko1@kent. edu

Tracey Weston
Middlebury College, USA
email: tweston@middlebury.edu

Julie Amador
University of Idaho, USA
email: jamador@uidaho.edu