EXPLORING TEACHER KNOWLEDGE AND NOTICING WITH EYE TRACKING AND 360 VIDEO

Karl W. Kosko
kkosko1@kent.edu

Christine K. Austin
causti17@kent.edu

Maryam Zolfaghari
mzolfagh@kent.edu

Kent State University

Professional noticing involves attending to and interpreting children's mathematical reasoning. In a similar manner, pedagogical content knowledge (PCK) is defined as the knowledge teachers need to interpret and respond to children's reasoning. The present study reports on an initial exploration of the relationship between these two constructs using eye-tracking technology and the PCK-Fractions measure. Results suggest a relationship between where teachers spend time focusing and their PCK scores.

Introduction

Professional noticing is an important skillset that involves attending to students' mathematical actions, interpreting their reasoning from those actions, and deciding how to respond next (Jacobs et al., 2010). Many examine a myriad of factors affecting how teachers attend to and interpret students' reasoning through teachers' professional beliefs, knowledge, and experiences (Jong et al., 2021; Yang et al., 2021b). Scheiner (2021) argued that beyond being influenced by specifically cognitive factors (such as teacher knowledge), noticing is "embodied, cultural and positional in important ways" (p. 90). Rather, it is the interplay between cognitive, cultural, and embodied experience (i.e., experiences mediated by physiological input) that may best explain the complexities inherent in teachers' professional noticing (Jong et al., 2021; Kosko et al., 2022).

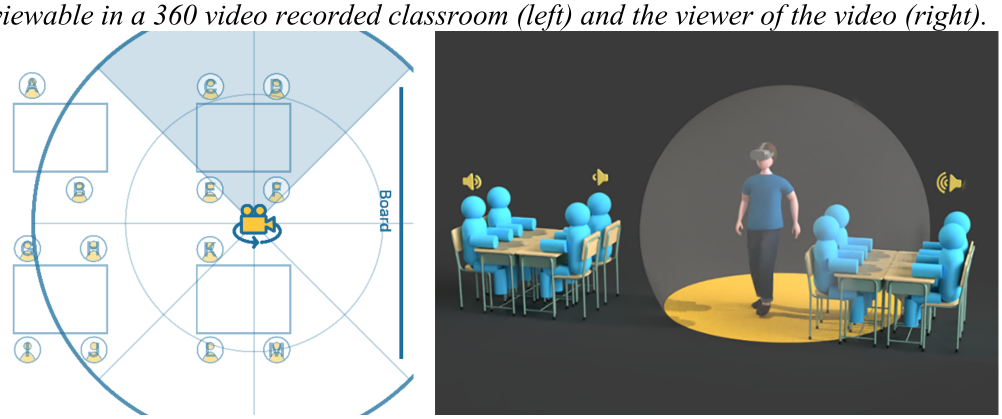
The present study seeks to bridge the gap between embodied and cognitive domains to better understand the nature of teachers' attending to and interpreting of children's mathematics. Specifically, we follow scholarship suggesting that teachers' change in eye-gaze (Huang et al., 2021) and field of view (Kosko et al., 2022) are associated with how teachers interpret students' mathematics. Such scholarship suggests *that* noticing is embodied, and there is mounting evidence for this connection. Yet, there is less description of *why* or *how* such noticing is embodied. Thus, the present study reports on analysis of preservice teachers' (PSTs) pedagogical content knowledge for fractions and how PSTs' embodied actions when viewing a 360 video are associated with such professional knowledge.

Theoretical Framework

Teacher Noticing

Professional noticing involves attending to key pedagogical events, interpreting these events, and deciding how to act based on such interpretations (Jacobs et al., 2010; Santagata et al., 2021). PSTs may initially attend to only generic aspects of a classroom recording such as the teacher's classroom management or students' behavior and engagement (Jacobs et al., 2010). Over time, they can transition to focusing on students' answers and then their procedures. Eventually, a teacher may improve the quality of their noticing such that it focuses on students conceptual reasoning. Quite often, such variations in quality of noticing are associated with the years of experience a teacher has (Yang et al., 2021). However, other factors can affect teachers' noticing. Although there are a multitude of factors that may explain a teachers' noticing (Scheiner, 2021), the present study focuses on two such factors for sake of simplicity: teachers' professional knowledge and physical (embodied) actions.

Figure 1
What is viewable in a 360 video recorded classroom (left) and the viewer of the video (right).



Evidence of the embodied nature of noticing stems from two areas of scholarship: eye-tracking research and use of virtual reality (VR) including 360 video. Scholars using eye-tracking technology tend to indicate that experienced teachers look at more students and have a more even gaze distribution (Huang et al., 2021; van den Bogert et al., 2014). Rather, experienced teachers "exhibit fewer task-irrelevant fixations with shorter durations, they also direct more fixations to student" (Huang et al., 2021a, p. 11) and across more students. Research utilizing 360 video has found corollary results. Specifically, 360 video records omnidirectionally and allows the viewer to choose where they may look from a fixed point in the classroom (see Figure 1). Studying PSTs' noticing with 360 video, Kosko et al. (2021) recorded their viewing sessions and compared their written interpretations of students' mathematics with which tables (i.e., groups of students) PSTs focused in their field of view (FOV). Findings indicated a relationship between how much time PSTs spent focusing on particular tables and the sophistication of their noticing. Later, Kosko et al. (2022) observed that PSTs who positioned students more centrally in their FOV were more likely to describe their conceptual reasoning than PSTs who placed the classroom teacher more centrally in their FOV.

There is significant scholarship seeking to examine the relationship between professional knowledge, such as mathematical knowledge for teaching (MKT), and noticing. Unfortunately, scholarship relating MKT and noticing often produces mixed results indicating MKT either has a negative, a positive, or no relationship with quality of professional noticing (Jong et al., 2021; Yang et al., 2021). One possibility for such mixed results is that other factors may mediate how teachers operationalize their professional knowledge in the act of noticing. Jong et al. (2021) suggest that focusing on subdomains of MKT to examine professional noticing may illuminate otherwise "hidden" (p. 162) relationships. Likewise, Scheiner (2021) suggests a similar approach. Given the mixed findings regarding the relationship between MKT and professional noticing, the present study follows such recommendations by focusing on PCK, but also by examining the role of PCK in noticing via embodied activity of PSTs when viewing 360 video.

Pedagogical Content Knowledge

PCK involves teachers' knowledge of classroom instruction and students' reasoning. As part of the MKT framework, Hill et al. (2008) specified different subdomains for PCK. Most relevant to the current paper is *knowledge of content and student* (KCS), which focuses on knowledge of students' mathematical thinking and their errors. Although many scholars examining MKT focus on both CK and PCK, there is often specific attention on KCS when studying PCK particularly (Tröbst et al.,2018; Zolfaghari et al., 2021). In constructing their initial construct map for PCK for fractions, Zolfaghari et al. (2021, in review) defined four hierarchical levels for teachers' understanding of students' fractions reasoning. At Level 1, teachers are able to assess whether children can partition a whole into a given part, but are not able to assess children's part-whole reasoning until Level 2. At Level 3, teachers can assess children's relational thinking of how to coordinate multiple fractions occurs at this level (e.g., $\frac{2}{3}+\frac{5}{8}$). Lastly, at Level 4, teachers can assess children's knowledge of fractions of fractions (i.e., what is $\frac{1}{3}$ of $\frac{2}{5}$). Attending to children's strategies and noticing their misconceptions is considered part of the professional noticing construct (Jacobs et al., 2010). There is emerging evidence that teachers at lower levels of PCK-Fractions attend less to students' actions when they work with such fractions (Kosko, 2022). The present study seeks to explore this relationship in more detail using the PCK-Fractions measure (Zolfaghari et al., 2021).

Summary and Context of Current Study

The relationship between professional noticing and PCK is both intuitively logical and advocated by the field. However, efforts to establish empirical evidence for this relationship have produced mixed results with some scholars finding positive associations, negative associations, or no observable relationship (Jong et al., 2021; Yang et al., 2021). By contrast, there is growing evidence for the role of embodied activity in professional noticing. More sophisticated noticing is associated with more focused attention (longer sustained durations) on students (Huang et al., 2021; Kosko et al., 2021). This study is exploratory and seeks to examine whether there is any relationship between PSTs' embodied actions, as measured by eye-tracking activity in viewing a 360 video, and their PCK for fractions. Thus, we sought to answer the research question: *Is there a relationship between PSTs' assessed PCK and their duration of eye-gaze behavior?*

Methods

Sample & Procedure

Participants included a convenience sample of 33 PSTs. Participants predominately identified as White and female (76.5%), with other participants including one Black female, five White males, one Hispanic female, and one Hispanic male. Participants were evenly divided between those preparing to teach upper elementary mathematics (51.5%) and those majoring in other educational disciplines (48.5%). Following recruitment, participants engaged in a 45-minute session where they first completed a demographic survey and the PCK-Fractions assessment. Validity evidence for PCK-Fractions has been collected across multiple studies (i.e., Zolfaghari et al., 2021; in review). The measure includes 17 multiple-choice items that assesses a teachers PCK for teaching and learning fractions. Dichotomously scored items are logistically converted to a continuous variables using Rasch modeling ($M = 0.17$, $SD = 0.84$).

Next, participating PSTs were provided an overview description of the 360 video they were about to watch using an eye-tracking enabled VR headset (Pico Neo 3 Eye). They were told that they would watch the video to assess children's mathematical thinking:

In this episode from Ms. M's fourth-grade class, several weeks have passed since students first learned about equivalent fractions. In this clip, Ms. M reviews equivalent fractions with students by having them use fraction strips to find an equivalent fraction to 5/6 and then 3/8.

PSTs were provided with a set of fraction strips to explore the topic. Next, PSTs put on the VR headset, calibrated the eye-tracking sensors to their eyes, and watched the 360 video of Ms. M's class. Afterwards, participants wrote the key concept they believed students were learning about, and then to "describe 2-3 moments that showed a child's thinking about the key idea." Eye-tracking data from viewing sessions were collected and analyzed with a machine learning algorithm developed to identify pupil fixations on specific individuals within the 360 video.

Analysis & Results

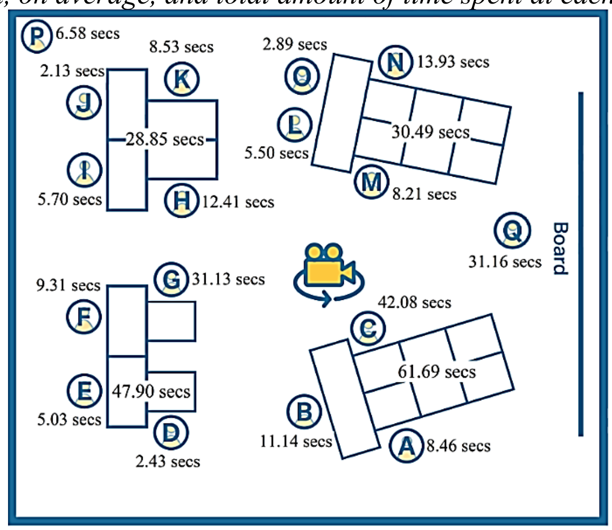
Using raw eye-tracking gaze data, summary statistics were computed by summing the number of seconds each PST looked at a specific student or teacher. For example, if the gaze data reported that a PST looked at student A twelve times, the sum of those 12 occurrences was taken. The sums per student were then taken collectively to report the number of seconds spent looking at a specific table (e.g., back left table) and the total amount of time looking at the two teachers in the room. Figure 2 displays the average amount of time looking at each student, teacher, and the sum of the seconds at each table. From the classroom map (Figure 2) PSTs, on average, spent more time looking at the right front and right back tables and students G, C, and teacher Q. Thus, for each participant there were five reported variables (back-left table, front-left table, back-right table, front-left table, teachers).

When assessing the relationship between a PSTs PCK-Fractions score and where they attended, results suggest correlations between a PSTs PCK and the back right table ($r(32) = 0.17$, $p = 0.349$) and the front left table ($r(34) = 0.16$, $p = 0.376$) were not statistically meaningful.

However, analysis revealed a statistically significant positive correlation between PSTs' PCK score and the amount of time looking at the back left table ($r(32) = 0.38$, $p = 0.029$). In comparison, there is a statistically significant negative correlation at $\alpha = 0.1$ level between a PST's PCK score and the front right table ($r(32) = -0.32$, $p = 0.074$). This insinuates that a PST with a low PCK score is more likely to look at the table by the camera while a PST with a higher PCK score is likely to turn around and look behind them.

Figure 2

Breakdown of gaze data, on average, and total amount of time spent at each table.



Note. P and Q represent the two teachers in the room.

Discussion

Results are preliminary but suggest a correlation between PSTs' PCK and the amount of time they spent focusing on different groups of students in the classroom. PSTs with higher PCK scores tended to spend more time focusing on the back-left table in the classroom. Important in interpreting this result is that halfway through the video, the teacher has a brief class discussion regarding equivalent fractions to $\frac{5}{6}$. At one point (2:26 to 2:47), students at the back-left table comment that they initially thought to simplify the fraction by dividing but didn't because "5 is prime." PSTs with PCK scores above 1.00 spent an average of 6.29 s in the 21 s interval gazing at this table, whereas PSTs with scores below 0.00 spent an average of 1.69 s. Notably, prior research with eye-tracking data suggests that more experienced teachers spend more time looking at students further away while novices focus only on those proximally close to them (Huang et al., 2021). Another factor is that higher PCK for fractions is associated with teachers' ability to assess children's arithmetic actions on fractions (Kosko, 2022). Given that students at the back-left table were describing their use of multiplication to find equivalent fractions, less time looking at such students may associate with a lack of assessing these students' mathematics.

Results here suggest that teachers' PCK may play a role not only in noticing students proximally further away, but also which such students are attended and when. In this particular case, PSTs with higher PCK scores focused on students describing their use of multiplication to find equivalent fractions, whereas students with lower PCK scores spent significantly less time doing so. This paper presents preliminary results suggesting a relationship between higher PCK-Fractions scores and more time attending to students who described their strategies for finding an equivalent fraction. Future study is needed to extend and elaborate on these findings. However, results suggest an important interaction between professional knowledge and noticing.

Acknowledgements

Research reported here received support from the National Science Foundation (NSF) through DRK-12 Grant #1908159. Any opinions, findings, and conclusions or recommendations in this paper are those of the author(s) and do not necessarily reflect the views of NSF.

References

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, *39*(4), 372–400.

Huang, Y., Miller, K. F., Cortina, K. S., & Richter, D. (2021). Teachers' professional vision in action. *Zeitschrift für Pädagogische Psychologie*. https://doi.org/10.1024/1010-0652/a000313

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.

Jong, C., Schack, E. O., Fisher, M. H., Thomas, J., & Dueber, D. (2021). What role does professional noticing play? Examining connections with affect and mathematical knowledge for teaching among preservice teachers. *ZDM–Mathematics Education*, *53*(1), 151-164.

Kosko, K. W. (2022). Pre-service teachers' professional noticing when viewing standard and holographic recordings of children's mathematics. International Electronic Journal of Mathematics Education, 17(4), em0706. https://doi.org/10.29333/iejme/12310

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), 824–841. https://doi.org/10.1177/0022487120939544

Kosko, K. W., Zolfaghari, M., & Heisler, J. L. (2022). Professional noticing as student-centered: Pre-service teachers' attending to students' mathematics in 360 video. *EURASIA Journal of Mathematics, Science and Technology Education, 18*(9), em2145.

Santagata, R., König, J., Scheiner, T., Nguyen, H., Adleff, A. K., Yang, X., & Kaiser, G. (2021). Mathematics teacher learning to notice: A systematic review of studies of video-based programs. *ZDM–Mathematics Education, 53* 119-134. https://doi.org/10.1007/s11858-020-01216-z

Scheiner, T. (2021). Towards a more comprehensive model of teacher noticing. *ZDM–Mathematics Education*, *53*(1), 85-94. https://doi.org/10.1007/s11858-020-01202-5

Tröbst, S., Kleickmann, T., Heinze, A., Bernholt, A., Rink, R., & Kunter, M. (2018). Teacher knowledge experiment: Testing mechanisms underlying the formation of preservice elementary school teachers' pedagogical content knowledge concerning fractions and fractional arithmetic. *Journal of Educational Psychology, 110*(8), 1049-1065.

van den Bogert, N., van Bruggen, J., Kostons, D., & Jochems, W. (2014). First steps into understanding teachers' visual perception of classroom events. *Teaching and Teacher Education, 37*, 208-216. https://doi.org/10.1016/j.tate.2013.09.001

Yang, X., König, J., & Kaiser, G. (2021). Growth of professional noticing of mathematics teachers: a comparative study of Chinese teachers noticing with different teaching experiences. *ZDM–Mathematics Education*, *53*(1), 29-42. https://doi.org/10.1007/s11858-020-01217-y

Zolfaghari, M., Austin, C. K., & Kosko, K. W. (2021). Exploring teachers' pedagogical content knowledge of teaching fractions. *Investigations in Mathematics Learning, 13(3), 230-248*. https://doi.org/10.1080/19477503.2021.1963145

Zolfaghari, M., Kosko, K. W., & Austin, C. K. (in review). Toward a Better Understanding of the Nature of Pedagogical Content Knowledge for Fractions: The Role of Experience. *Investigations in Mathematics Learning.*