



# Using authentic video clips of classroom instruction to capture teachers' moment-to-moment perceiving as knowledge-filtered noticing

Nicole B. Kersting<sup>1</sup> · James E. Smith<sup>1</sup> · Beau Vezino<sup>1</sup>

Accepted: 27 October 2020 / Published online: 3 January 2021  
© FIZ Karlsruhe 2021

## Abstract

In this article, we report on the development of a novel, video-based measure of teachers' moment-to-moment noticing as knowledge-filtered perception. We developed items to capture teachers' perception of similarity of their own teaching to the teaching shown in three short video clips of authentic classroom instruction. We describe the item design and relate teachers' moment-to-moment noticing to their reflective noticing as measured by judgements of similarity teachers provided after viewing each video. Consistent with theory, correlations were of moderate size and provided evidence that the measures captured somewhat different information. We suggest that the difference can be explained by different cognitive processes: the moment-to-moment measure primarily captured noticing as a function of bottom-up (nonconscious) processes, while reflective noticing engaged top-down (conscious) processes. We conclude by considering strengths and limitations of this novel approach and the usefulness of differentiating between bottom-up and top-down processes to characterize existing measures of teacher noticing.

## 1 Introduction

Interest in research on teacher noticing has been growing over the past decade, at least in part because of its promise for teacher learning (Russ et al. 2016; Sherin and Star 2011). Typically, learning to notice involves the exploration and analysis of teaching outside the classroom through lesson videos, which affords rich discussions and the consideration of multiple perspectives. In this context, noticing and associated measures capture noticing as a reflective skill. Measures of moment-to-moment noticing, on the other hand, have remained scarce, despite the value they bring to understanding what teachers notice and attend to in an actual classroom situation. In this paper we report on a novel and innovative

approach to measuring moment-to-moment noticing. Specifically, we designed video-based items to measure perceived similarity of teachers' own teaching to the teaching shown in short video clips of classroom instruction and examined the relationship between such moment-to-moment measures to reflective noticing as captured by teachers' holistic similarity ratings.

### 1.1 The construct of teacher noticing

Far from being a single, uniform construct, different notions of noticing have developed (Choy et al. 2013; Sherin et al. 2011a, b). One notion focuses on teachers' ability to know what to attend to in a classroom and how to attend to it, which requires underlying knowledge and specific supporting skills (Sherin and Star 2011). This notion is closely related to the construct of professional vision as described by Goodwin (1994), which incorporates, next to the cognitive aspects of noticing (knowledge-based perception), a socio-culturally constructed understanding of what is important to notice. In contrast, a more literal notion of noticing focuses on what teachers visually perceive or what captures their attention and not necessarily what is important. Other researchers have proposed that noticing not only

---

This material is based upon work supported by the National Science Foundation under Grant no. 1720866. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

---

✉ Nicole B. Kersting  
nickik@email.arizona.edu

<sup>1</sup> College of Education, University of Arizona, 1430 2nd Street, Tucson, AZ 85721, USA

encompasses perception and interpretation but also includes decision-making (Jacobs et al. 2010).

Clearly distinguishing between different notions of noticing is not only important from a theoretical perspective for research and studies on noticing, but also for the development of measures. In our study, we viewed noticing through a cognitive lens and less through a sociocultural lens as described by Goodwin. We aimed to measure moment-to-moment knowledge-filtered perception, which we conceptualized as a noticing task that is filtered through teachers' knowledge of their own practice.

Beyond reporting on the specific items we developed, this novel, video-based approach has potential to measure different notions of moment-to-moment noticing. It could be used to measure visual perception and attention, knowledge-driven perception, or professional vision by selecting different types of classroom videos and by varying associated task prompts.

## 1.2 Measures of teacher noticing

The majority of measures of teacher noticing capture noticing as a reflective skill; fewer instruments measure noticing as it happens. To measure noticing as a reflective skill, teachers may view videotaped classroom instruction, either short video clips or longer lesson segments of their own or other teachers' teaching and identify and interpret moments in the video they notice as relevant (Karsenty and Sherin 2017; Santagata and Guarino 2011). In other studies, teachers are primed to focus on specific aspects of teaching (Blomberg et al. 2014; Kersting et al. 2012, 2020). One version of these measures prompts teachers to stop the video when they notice an event and provide either verbal or written interpretations of the event, while others ask teachers to view the entire clip before responding (Kersting et al. 2012). Measures of this general design are typically not timed. A strength of these measures is that they capture knowledge- and skill-driven perception (Santagata and Yeh 2016) and thereby can provide evidence of teacher learning. A limitation of these measures is that it is less clear whether teachers can enact skills being measured in real time in the classroom. Further, these measures may not capture everything teachers notice because some instances may not be deemed relevant enough to report but may affect their noticing of later events. Lastly, such noticing creates the potential for reinterpreting specific moments from a normative stance rather than capturing each moment of noticing (Sherin and Star 2011).

Some studies attempt to measure immersed noticing through speak-aloud commentaries. In such studies, teachers view either video of their own teaching or lesson videos from other teachers without the possibility of stopping the video and provide an ongoing commentary of what they notice (Carter et al. 1988). Without the possibility of

stopping the video, such measures capture teachers' ability to selectively attend from moment-to-moment to particular aspects of the teaching. These measures are well suited to mimic the sensory overload in actual classrooms and thus are more likely to provide evidence of what teachers attend to in a more authentic teaching situation. Such studies have been able to identify differences in the quality of noticing between expert and novice teachers (Carter et al. 1988). A limitation of ongoing commentary, however, is that perception will be affected during speaking, which may lead teachers to miss new events as they complete their comments about previous events.

A different kind of measure of immersed noticing employs eye-tracking to capture teachers' eye movements as they watch videos (van den Bogert et al. 2014) or actively teach in a classroom (Cortina et al. 2015). Such studies have been able to show that expert teachers' attention is more focused than that of novices and that patterns of eye movement are related to knowledge (Wolff et al. 2017; Cortina et al. 2015). An obvious strength of these measures is their nonconscious nature, as it is virtually impossible to consciously control eye movement at length in the face of overwhelming moment-to-moment perceptual information. A potential limitation, on the other hand, is that eye-tracking data may be noisy and capture aspects of teacher attention that are difficult to fully interpret. That is, because teacher attention may be purposeful (or not), it may be difficult to infer whether the teacher's gaze was driven to a specific event in a video clip or classroom by their underlying knowledge or by some other aspect.

We only know of one measure that aims to capture teachers' professional noticing as in the moment decision-making by constraining response time (Jeschke et al. 2019). In this measure of action-related skills, teachers view short video clips and are asked to respond verbally within seconds or the response times out. A unique and hybrid measure in this context are head mounted cameras (Karsenty and Sherin 2017; Sherin et al. 2011b), which teachers turn on to capture something they notice to be important while teaching and are asked to reflect on later. A useful way to compare measures that capture noticing as a reflective versus moment-to-moment skills is to consider the primary cognitive processes involved.

## 1.3 Cognitive processes involved in noticing as a potentially useful approach to characterize existing measures

Broadly speaking, research in cognitive science is consistent with the way teacher noticing is conceptualized while adding important nuance. Recent research in visual and auditory perception has provided empirical evidence that what we perceive in the environment is influenced by conscious and

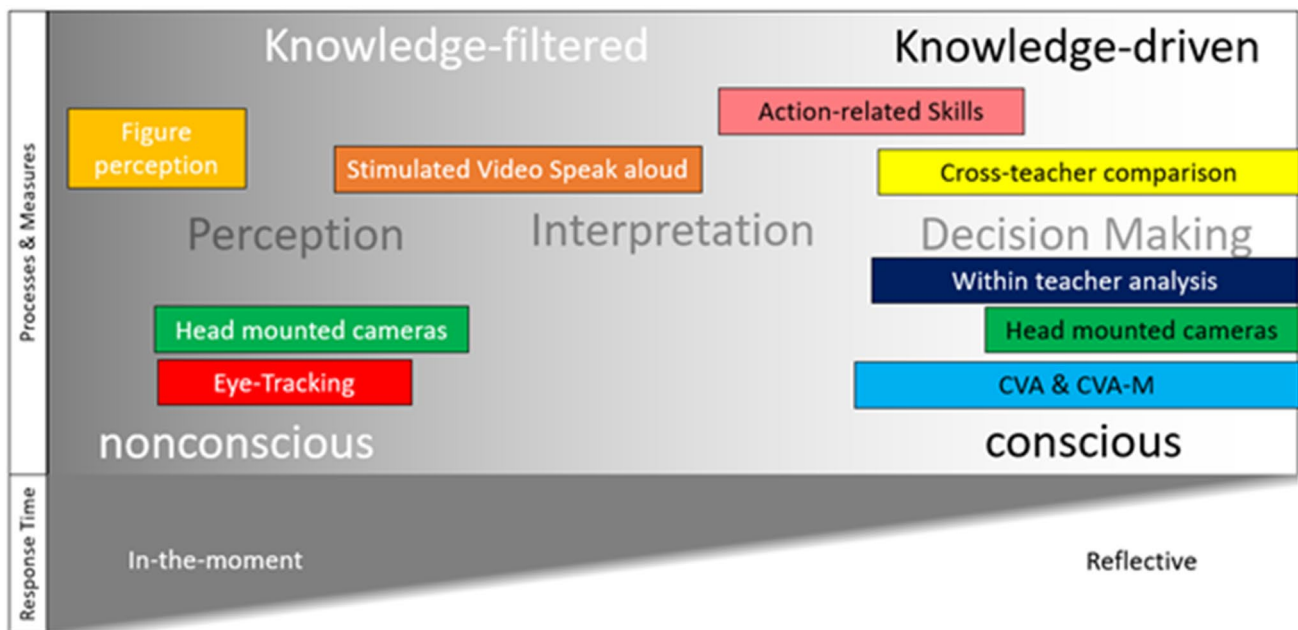
nonconscious expectations (de Lange et al. 2018). Researchers theorize that what we attend to is a combination of a conscious focus (top-down) and nonconscious, perceptual selection (bottom-up) (Lavie et al. 2004). Thus, top-down approaches may be described as *knowledge-driven* perception, are more effortful and explain why novel situations require more thoughtful focus. Bottom-up approaches may be described as *knowledge-filtered* perception and reflect noticing in familiar situations in which we seem to intuitively or automatically know where and what to look for.

From this perspective, measures of noticing that ask teachers to view a video clip and respond to it in writing without time constraints likely reflect some combination of bottom-up and top-down approaches. It is difficult to determine whether any given response represents what teachers effortlessly noticed, or if it represents teachers deliberate, knowledge-driven attention to specific aspects. For measures that prompt teachers to stop the video when they notice something and explain what they notice it is similarly difficult to determine which process predominantly led to teachers' in the moment noticing.

Speak-alouds without stopping the video are, at least, theoretically better suited to differentiate between both processes. With increasing lengths of the classroom video, it

is likely that teacher noticing reflects their bottom-up processes because of sensory overload. Similarly, eye-tracking measures almost exclusively capture effortless, bottom-up processes as the assumption is that you cannot consciously control where you are looking. One reason to consider the cognitive processes involved in noticing is that measures of bottom-up processes are more likely to mimic noticing in the classroom. In other words, those instances teachers can notice effortlessly may be closer to what teachers are likely to notice in an authentic classroom situation, which directly affects instructional decision-making. Thus, taking the prevalence of cognitive processes (bottom-up or top-down) involved in teacher noticing in to consideration might provide a useful way of characterizing existing measures along a continuum of nonconscious to conscious, as shown in Fig. 1. Note that the measures (colored boxes) serve as examples and are not intended to be a comprehensive list of existing instruments.

On the far left of the continuum, we situated visual-perceptual research. Such research focuses primarily on the visual system ranging from neurophysiological studies to developmental studies. Within studies of noticing, specifically in teacher noticing, measures assume that individual's visual systems are working and thus no measures are needed.



**Fig. 1** Knowledge-filtered perception engages bottom-up or non-conscious processes that affect what is noticed in the moment or moment-to-moment. Knowledge-driven perception employs top-down or conscious processes that are utilized in reflective noticing and require conscious effort. From left to right example measures increasingly allow for more top-down processes. From the left, measures of basic visual figure detection (gold; Peterson and Salvaggio 2008), eye-tracking (red; Wolff et al. 2017), stimulated video speak-alouds (orange; Carter et al. 1988), action-related skills (pink;

Jeschke et al. 2019), CVA and CVA-M (blue; Kersting et al. 2012), cross-teacher comparison (yellow; Stockero and Rupnow 2017), within teacher analysis (navy; van Es and Sherin 2008). A unique measure within this conception are head mounted cameras (green; Sherin et al. 2011b) which asks teachers to quickly capture something they interpret to be important while teaching which they are then asked to reflect upon later, represented both under nonconscious and conscious access

Studies using eye-tracking may be located mostly along the continuum within perception with an overlap into interpretation reflecting informed perception. Eye-tracking measures capture mainly nonconscious (bottom-up) processes. Most studies of professional noticing or professional vision focus primarily on how knowledge shapes perception by relying on conscious or reflective interpretation in which teachers are asked to reason about what they knowingly perceived (on the right side of Fig. 1).

Which of the two processes is more prevalent may depend on specifics, such as task, video clips, viewing and response time constraints. Measures of noticing that ask teachers to stop the video the moment they notice and explain, might tap more into teachers' nonconscious bottom-up processes, while measures that allow for reflection might capture predominantly top-down processes. Research on decision-making, which examines how teachers use what they perceive and interpret to make instructional decisions, is situated on the right end of the continuum. Approximate measures of teachers' decision making (e.g., such as the CVA-M) may primarily capture top-down or conscious processes because no response time constraints are placed on teachers and teachers can view the video multiple times even though time stamps saved from participants suggest immediate responses and a single viewing.

As shown in Fig. 1, the relative sparsity of existing instruments that measure knowledge-filtered perception and that afford substantive interpretation of what is noticed in efficient ways motivated the development of the items we report on. We investigate the following two research questions:

1. Can we design a moment-to-moment measure of teachers' knowledge-filtered perception of similarity between teachers' own teaching and the teaching shown in short video clips of authentic classroom teaching?
2. What is the relationship between this moment-to-moment measure of teachers' knowledge-filtered perception of similarity and a reflective measure of similarity as measured by knowledge-driven similarity ratings of those same teachers?

## 2 Methods

### 2.1 Sample

Two hundred and eighty-four 4th and 5th grade teachers from one of the largest school districts in the US completed the two noticing measures used in this study and a background survey. About 40 percent of participants reported that they taught 4th grade; another 40 percent taught 5th grade. The remaining teachers reported teaching multiple grades including 4th or 5th grade (17%), while a few

teachers reported teaching outside of our target grades (3%). The majority of the participating teachers stated that they obtained their teaching credential through a college or university (77%) and most held clear credentials (85%). Two-thirds of the participating teachers indicated to have at least 10 years (69%) classroom experience, and more than half of participating teachers had taught mathematics for at least 15 years. About 40 percent of teachers reported having majored in elementary education. The remaining teachers reported diverse undergraduate majors and indicated attainment of their teaching credential through a graduate program. Although the sample is a convenience sample with all the known limitations, teacher backgrounds and experiences were sufficiently diverse and thus teachers' noticing abilities are likely to vary.

### 2.2 Measures

#### 2.2.1 Developing items to measure moment-to-moment teacher noticing

The goal of the initial item development effort was to design items that capture teachers' perceptions of their own teaching, measured as moment-to-moment ratings of similarity with the teaching shown in short video clips of mathematics instruction. We hypothesized that teachers' moment-to-moment ratings would be driven by teachers' knowledge-filtered perception (bottom-up processes) and affect what teachers notice. We primed teachers to focus specifically on the mathematics by posing the following task for each of the three videos we selected "Using the controls—thumbs up and thumbs down—please indicate how similar your own teaching is to the way the **math** is taught in this video clip".

#### 2.2.2 Selection of video clips

We selected three short video clips of authentic classroom instruction, about 1–2 min each, that varied in terms of the depth of the mathematics and the mathematical work students engaged in. Clip 1 features a teacher explanation prompted by a student question, Clip 2 shows students reasoning about the solution to a novel problem, and Clip 3 depicts students modeling through manipulative use. Below, we describe the first video in more detail as an illustrative example.

The first clip features a teaching episode in which the teacher addresses a student question about the standard algorithm of multiplication with the whole class. The question is about the purpose of using a "0". To address the question, the teacher poses a problem on the white board and solves it together with the students. After multiplying by the number in the ones-place, the teacher moves on to multiplying the number in the tens-place. When the teacher writes down

the partial product starting in the tens-place, she adds the 0 in the ones-place. She then refers to the “0” as placeholder, holding the space in the ones-place. Although this explanation may be useful because it is easy to remember, it falls short of making the underlying mathematics visible; that is, although it may seem that we multiply two single-digit integers, in actuality we multiply a single digit integer and a number in the tens.

We selected this video because we hypothesized that the teaching in the video had sufficient variability to produce differences in teachers' moment-to-moment perceptions of similarity. For example, we anticipated that teachers who in their own classrooms strive to make the underlying mathematics visible may notice the limitations of the placeholder explanation and therefore perceive dissimilarity at that point in the video, while teachers, less focused on the depth of the mathematics, may not notice the limitation and therefore not identify dissimilarity. Similarly, we anticipated that teachers who themselves seek to engage students in doing the mathematical work may notice dissimilarity to the teaching shown in the video clip.

The remaining two videos varied along those same dimensions. In Video 2, the teacher presents a word problem that translates into 1 divided by  $\frac{2}{3}$  to have students think conceptually about what it means to divide by a fractional amount. After posing the problem, the teacher invites students to share their thoughts about how to solve the problem. The third video features a teaching episode on modeling multiplication of fractions through paper folding using the area model (“hamburger” and “hot dog” folding). The teacher scaffolds both the activity and the mathematics for the students who follow along and obtain the correct answer by counting how many pieces are double shaded (numerator) out of the total number of pieces (denominator).

Broadly speaking, we may characterize the first clip as a well-executed teacher explanation, focused on procedural not conceptual understanding, of how to use the traditional multiplication algorithm with the teacher doing most of the mathematical work. We may characterize the second video as an example of teaching that is focused on a deeper understanding of the mathematics with students doing most of the mathematical work, leveraging their prior knowledge to solve a novel problem in an informal way. The last video shows a focus on active engagement with the mathematics using manipulatives, but without making the deeper mathematical ideas underlying multiplication of fractions explicit.

### 2.2.3 Data collection that yielded the time series data

To capture teachers' perceived similarity with the teaching shown in the video clips, we asked teachers to view each clip and, using a thumbs-up and down button, indicate similarity moment-to-moment on a scale ranging from  $-50$  to  $+50$ .

On this scale,  $+50$  indicates teachers' own teaching of the mathematics to be highly similar,  $0$  indicates not similar or dissimilar, and  $-50$  indicates teaching that is highly dissimilar. Teachers similarity ratings were recorded each second, producing complex time-series data for each teacher for each clip.

We hypothesized that this item design would greatly reduce opportunities for engaging reflective skills and ensure that teachers rely on knowledge-filtered perception when providing their similarity ratings. Similar designs have been used in psychology to capture automatic (bottom-up) processes and reduce the activation of conscious (top-down) processes due to time constraints and the requirement of continuous responses (Nosek et al. 2011).

To further ensure that teachers continuously provide moment-to-moment ratings of similarity, the interface gives a warning after 4 s of inactivity and stops the video at 6 s if no new ratings were made. We also built in a decay of 5 points per second pulling towards 0 to entice teachers to continuously affirm their ratings. Finally, to reduce the possibility for reflective analysis of the teaching events, teachers did not have the option to stop or rewind the video or to re-record their responses. Figure 2 shows Item 1 on the <http://www.teknoclips.org> interface.

### 2.2.4 Rating scale items assessing similarity

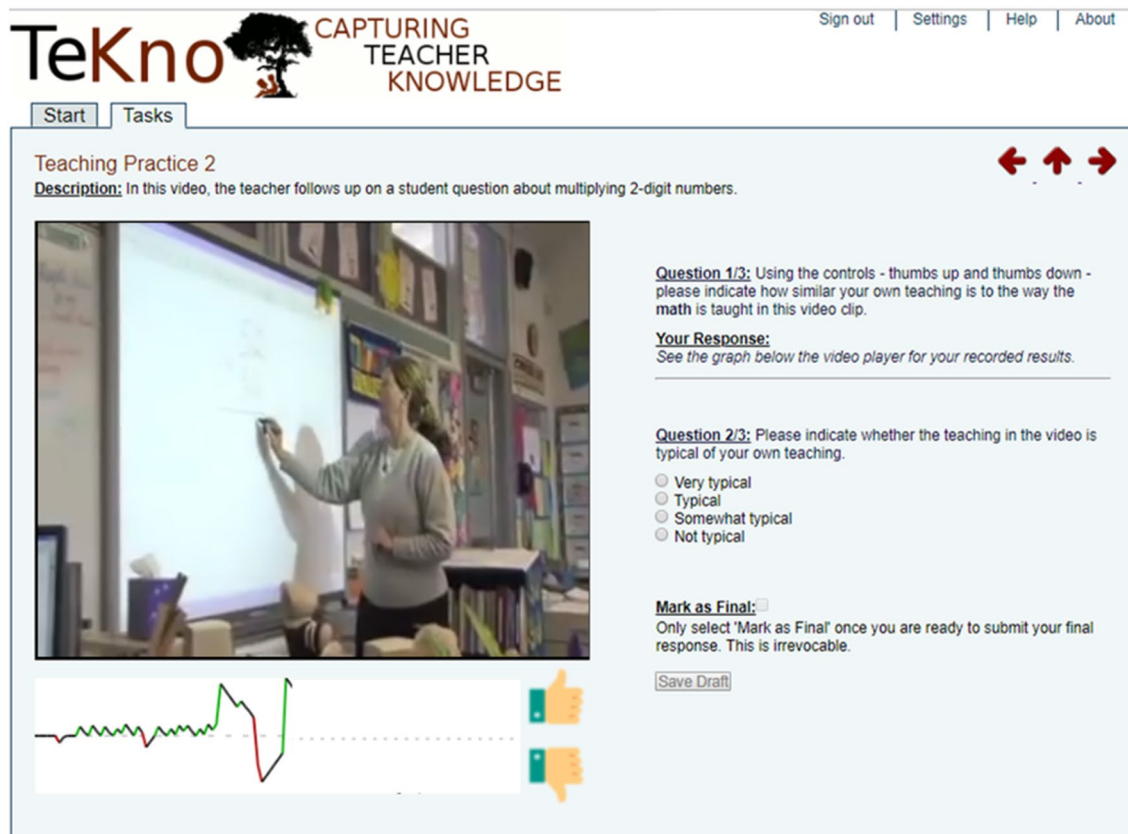
After completing the moment-to-moment ratings of perceived similarity, we also asked teachers to provide a holistic rating of perceived similarity as a reflective measure. Teachers holistically rated how similar the teaching of the mathematics in each video is to their own teaching on a 4-point scale (4 = strongly agree, 3 = agree, 2 = disagree, and 1 = strongly disagree). For each clip, we asked teachers to rate a unique and clip-specific statement focused on the mathematics: “The way this teacher clarifies how to use the algorithm for multiplying whole numbers is similar to the way I help my students deepen their understanding of the math” for Clip 1; “The way the teacher allows students to struggle with the math is similar to the way I teach” for Clip 2; and “The way this teacher uses manipulatives to multiplication of fractions is similar to the way I help my students deepen their understanding of the math” for Clip 3.

## 3 Analysis and results

### 3.1 Moment-to moment similarity ratings as evidence of teachers' knowledge-filtered perception

Individual teacher ratings can be interpreted as teachers' moment-to-moment noticing of similarity or dissimilarity

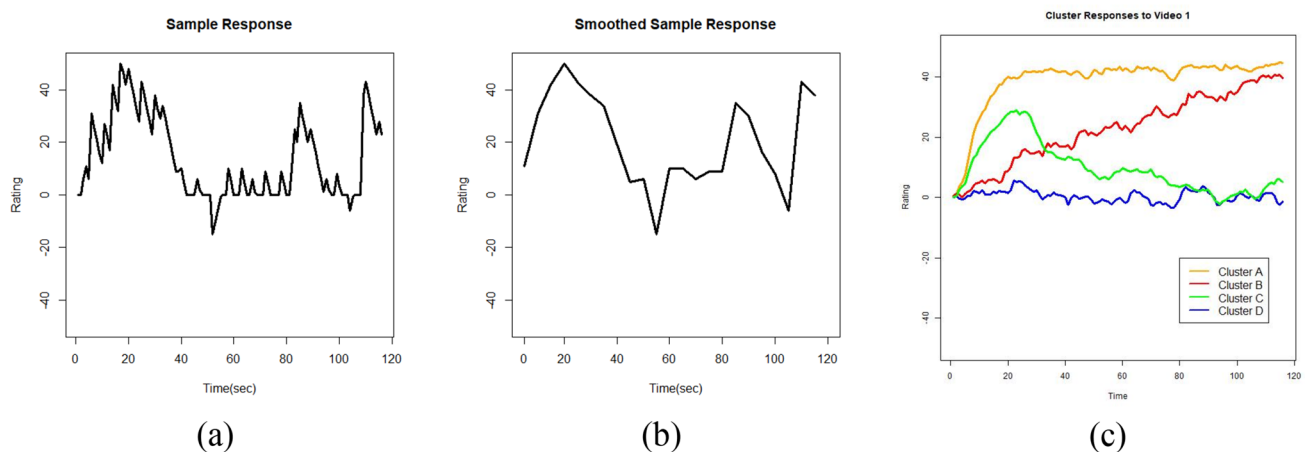




**Fig. 2** Moment-to-moment measure of teachers' knowledge-filtered perceptions

of their own teaching to teaching events related to the mathematics in the video clips. Of particular interest are steep rises and steep declines as they represent salient instances of perceived similarity or dissimilarity. As shown in Fig. 3a, during the first 20 s of the video in which the teacher takes up a student's mathematical question about the algorithm, the responding teacher notices similarity to their own teaching.

The slow decrease from 20 to around 35 s, during which the teacher in the video begins solving the example problem on the board, is noticed as becoming increasingly less similar. The sharp increase at around 50 s corresponds to the teacher in the video carefully using place value language, which the responding teacher notices as being relatively more similar to their teaching. Between 80 and 105 s the teacher in the



**Fig. 3** Single raw teacher response, single smoothed teacher response, Clip 1 4-cluster solution

video introduces the “0” as placeholder, which is perceived by the responding teacher as being similar to their own teaching, while the subsequent explanation of its function in the algorithm is noticed as being increasingly dissimilar.

It is important to note that what teachers are noticing as similar or dissimilar depends on their knowledge-filtered perception. We asked teachers to focus on similarity related to the mathematics and interpretations reflect this framing. It is, however, possible that some teachers were not able to maintain this framing as they engaged in this task and noticed similarity more broadly. For example, they may perceive similarity in classroom structure and activities or teacher moves, which introduces noise into the data. In either case, *noticing* reveals the knowledge-filtered perception of individual teachers.

### 3.2 Analyzing teachers' moment-to-moment similarity ratings captured as time-series data

Some studies might focus on individual teachers' noticing. Other others may seek to understand teacher affinity to relevant underlying constructs, such as reform-oriented versus traditional teaching or professional vision. In these cases, identifying teachers with similar noticing response patterns might be of interest and justify loss of detail inherent in aggregation.

To identify groups of teachers with similar response patterns, we clustered teachers' moment-to-moment ratings. We analyzed the time-series data reflecting teachers' moment-to-moment similarity ratings in three steps. To reduce noise in the data, specifically due to decay, we first applied a 5-s convolutional window (Goodfellow et al. 2016). As a result, many of the small changes in similarity observable in Fig. 3a are removed in the “smoothed” data shown in Fig. 3b. Both (a) and (b) represent individual teachers' knowledge-filtered perception of similarity. Second, we clustered the smoothed data using Gaussian mixture modeling (Scrucca et al. 2016) to identify groups of teachers based on similar patterns of noticing. We obtained a 4-cluster solution for Clip 1 (shown in Fig. 3c), indicating four distinct groups of teachers. We obtained a 5-cluster solution for Clip 2, and a 4-cluster solution for Clip 3 (both not shown here).

### 3.3 Cluster interpretation

As shown in Fig. 3c, teachers' smoothed moment-to-moment ratings ( $N=284$ ) reduced to four clusters. Cluster A, represented by the orange line, can be described as “up and over”, and shows little variability. It indicates that teachers' in this cluster perceived the teaching of standard multiplication algorithm to be highly similar to their own teaching.

Cluster B shows increasing perceived similarity (red line) moving from not similar or dissimilar to highly similar by

the end of the clip. This cluster reflects that responding teachers' increasingly notice the way the teacher explains the algorithm and engages the students in the mathematics is similar to their own teaching. The increasing pattern may provide evidence that prior noticing affects later noticing.

Teachers in Cluster C (green line) appear to notice the quality of the mathematical explanation because the cluster pattern mirrors changes in the depth of the mathematics. While responding teachers in this group initially may notice similarity to the teacher's careful and intentional use of the place value language, they notice increasing dissimilarity as the teacher in the video misstates the partial products of  $50 \times 6$  as  $5 \times 6$ . The individual response shown in Fig. 3a, b is part of this pattern.

Cluster D can be described as “flatliners” (blue line) and shows little variability. It indicates from start to finish little or no similarity between the teaching in the video. It is difficult to interpret this cluster with certainty. Assuming that all teachers do teach the multiplication algorithm as part of the curriculum, they may teach it in a different way or engage students with the mathematics in different ways. It is also possible that some teachers in this group did not complete the task as intended. A limitation of our noticing task is that expressed dissimilarity does not necessarily provide enough information on what those teachers actually do.

For the purpose of this study, we rank-ordered clusters in terms of overall perceived similarity (Cluster A = highly similar = 4, Cluster B = similar = 3, Cluster C = little similar somewhat dissimilar = 2, and Cluster D = dissimilar = 1) to be able to relate them to teachers' reflective noticing scores. Although not reported on here, clusters for Clips 2 (5 clusters) and 3 (4 clusters) were similarly interpretable and rank-ordered for analysis.

### 3.4 Teachers holistic self-ratings as reflective measure of perceived similarity

Distributions for teachers' holistic ratings of similarity were fairly consistent across clips. More than two thirds of teachers agreed or strongly agreed that the way the teacher explains the algorithm is similar to how they explain it, while less than a third disagreed. For Clip 2, three quarters of the teachers agreed or strongly agreed that their “own students productively struggle with the mathematics in similar ways the students in the video do”. This is interesting and does not reflect findings from observational studies of teaching. The high endorsement might indicate that teachers did not notice the more nuanced qualities that constitute productive struggle and instead noticed that the teacher in the video poses a problem that is collaboratively worked on. It is also possible that normative understandings about high quality instruction influenced teachers' reflective similarity rating. For Clip 3, about 75% of teachers agreed or strongly agreed

**Table 1** Teachers holistic ratings of perceived similarity of teaching shown in video clips

|              | Strongly agree | Agree     | Disagree | Strongly disagree |
|--------------|----------------|-----------|----------|-------------------|
| Algorithm    | 65 (23%)       | 140 (49%) | 63 (22%) | 16 (6%)           |
| Struggle     | 77 (27%)       | 170 (60%) | 35 (12%) | 2 (1%)            |
| Manipulative | 85 (30%)       | 132 (46%) | 55 (19%) | 12 (4%)           |

The percentages may not be 100% due to rounding

**Table 2** Correlations between teachers' rank-ordered cluster membership and holistic similarity rating by clip

|                               | Moment-to-moment similarity clusters |                            |                            |
|-------------------------------|--------------------------------------|----------------------------|----------------------------|
|                               | Clip 1                               | Clip 2                     | Clip 3                     |
| Reflective similarity         |                                      |                            |                            |
| Clip 1: algorithm explanation | 0.275***<br>[0.157, 0.373]           |                            |                            |
| Clip 2: student struggle      |                                      | 0.358***<br>[0.253, 0.456] |                            |
| Clip 3: manipulative use      |                                      |                            | 0.369***<br>[0.245, 0.432] |

Values in square brackets indicate the 95% confidence interval for each correlation. \*Indicates  $p < .05$ . \*\* Indicates  $p < .01$ . \*\*\* Indicates  $p < .001$

that the way manipulatives were used to deepen the students' understanding of the math is similar to their own teaching.

Taken together, the holistic ratings suggest that the large majority of responding teachers perceive the teaching shown in all three video clips as similar to their own teaching although the videos exemplify three distinct styles of teaching the mathematics, suggesting measurement error or response bias. Next, we explore how these holistic ratings relate to teachers' clustered moment-to-moment ratings of perceived similarity.

### 3.5 Moment-to moment similarity clusters compared with teachers' holistic self-ratings

To better understand the relationship between teachers' moment-to-moment and their reflective similarity measures, we correlated teachers' cluster membership, rank-ordered for similarity, with teachers' holistic ratings. Correlations are shown in Table 1.

Table 2 shows that teachers' moment-to moment-perceptions of similarity as measured by their rank-ordered cluster membership show medium size correlations with teachers' holistic ratings (Clip 1:  $r = 0.275$ ,  $p < 0.001$ ; Clip 2:  $r = 0.358$ ,  $p < 0.001$ ; and Clip 3:  $r = 0.369$ ,  $p < 0.001$ ). The

correlations provide empirical evidence that both measures capture perceived similarity as we expected. The moderate size of the correlations, however, also indicates important differences between teachers' noticed similarity. We suggest that the difference can be explained by different cognitive processes: the moment-to-moment measure primarily captures noticing as a function of bottom-up (nonconscious) processes, while reflective noticing engages top-down (conscious) processes.

These results are consistent with both theory and empirical studies on implicit measures (Hedge et al. 2018) and provide evidence of reflective and possibly normative processes altering teachers' perceptions (Nosek et al. 2011). The moment-to-moment similarity ratings would be considered more accurately reflecting similarity and be closer to what teachers can actually notice and attend to in their own classroom, while the holistic ratings would be more likely to reflect intentional or unintentional bias, either perceptual or normative.

## 4 Discussion

In this article, we reported on the development of a novel video-based approach to measuring moment-to-moment noticing as teachers' knowledge-filtered perception. The items we developed were designed to capture teachers' perceived similarity of their own teaching to the teaching shown in video clips. We found that teachers' moment-to-moment measures were moderately and positively related to their reflective measure of similarity. We observed that the majority of variance in each measure is unique, which likely indicates differences between measuring bottom-up and top-down perceptual processes. In other words, similarity as noticed by teachers' moment-to-moment through knowledge-filtered perception differs notably from similarity based on reflective noticing. Our findings are consistent with theory and studies on implicit measures that "attempt to capture the psychological causes of social perception, judgment, and action that might not be accessible through introspective experience or be reported when asked, even if the respondent could report them accurately" (Nosek et al. 2011, p. 152). Based on the promising findings, this novel approach, which offers several advantages, warrants further study to more fully explore its usefulness for measuring teacher moment-to-moment knowledge-filtered noticing.

First, the video-based measure is fast, easy, and scalable and can complement existing measures of in-the-classroom noticing, such as eye-tracking and mounted cameras, as an efficient and cost-effective outside the classroom option. Second, the basic item design, with its continuous ratings, video stopping and decay functions, likely captures what is automatically and truly noticed. Third, interpreting what is



being noticed might be fairly straightforward because teachers' moment-to-moment ratings can be mapped on the teaching events in the video clips, provided the task is sufficiently focused and provides adequate priming. Another strength of this approach is that it can be modified to measure different notions of noticing in the moment, including professional noticing and professional vision, constructs for which moment-to-moment measures have remained scarce due to the complexity and invisibility of in-the-moment teacher noticing (Jacobs 2017). A further strength of this approach is that moment-to-moment noticing can be analyzed at the individual and at the group level through clustering. While the time-series data may be particularly useful to identify very detailed instances of what a single teacher noticed, for example, for diagnostic purposes or to document learning to notice over time, the clusters are useful to understand larger patterns of noticing for groups of teachers.

At the same time, individualized and cluster or group level measures also pose some challenges to interpretation because the broader patterns captured in the clusters might lead to interpretations that are not fully reflected in teachers' individual noticing. Thus, more work is needed to better understand in which kind of studies individual or group level noticing measures are more informative.

Priming is another question that deserves further investigation as it directly affects the meaning of scores. In this study, we primed teachers to perceive similarity focused on the mathematics. However, there is some evidence in individual responses that may reflect noticing of non-mathematical events, most notably interpersonal teacher comments. How to clearly and effectively frame the task, including priming, will be instrumental to interpreting individual and group level noticing with confidence. One can envision task prompts to be very open, such as "Indicate what you like about the teaching in this video clip" or more narrowly focused "Indicate when student thinking is made visible".

A related and potentially useful design feature supporting interpretability is the selection of video clips. It appears that video clips that prompt greater variability in knowledge-filtered perception both at the individual and the group level provide more information to anchor interpretation. In our study, noticing trajectories that showed little variation were more difficult to interpret than those with more variation. Selecting video clips with specific teaching events that align with or are relevant to different noticing notions may allow greater interpretative certainty.

For this article we analyzed teacher noticing for each video clip separately. At the outset of the study, however, we conceptualized video clips as items that together form a measure of perceived similarity. Figuring out ways to combine noticing across clips in meaningful ways will provide opportunities to conduct more in-depth psychometric analyses. Some implicit measures developed within psychology

have been found to be unreliable by traditional standards but highly predictive of actual behavior (Dang et al. 2020). One way to investigate this further is to explore the relationship between this moment-to-moment measure of noticing and decision-making in real classrooms.

Finally, we suggested organizing measures of teacher noticing along a continuum of conscious access reflected in underlying cognitive processes. On this continuum, we may envision this measure to fill a noticeable gap in current measures of knowledge-filtered, nonconscious, bottom-up processes. Whether conceptualizing noticing measures from this cognitive process perspective will be beneficial to research on teacher noticing requires further study.

## References

- Blomberg, G., Sherin, M. G., Renkl, A., Gloger, I., & Seidel, T. (2014). Understanding video as a tool for teacher education: Investigating instructional strategies to promote reflection. *Instructional Science*, 42(3), 443–463.
- Carter, K., Cushing, K., Sabers, D., Stein, R., & Berliner, D. C. (1988). Expert–novice differences in perceiving and processing visual classroom information. *Journal of Teacher Education*, 39(3), 25–31.
- Choy, D., Wong, A. F. L., Lim, K. M., & Chong, S. (2013). Beginning teachers' perceptions of their pedagogical knowledge and skills in teaching: A three year study. *Australian Journal of Teacher Education*, 38(5), 68–79.
- Cortina, K. S., Miller, K. F., McKenzie, R., & Epstein, A. (2015). Where low and high inference data converge: Validation of CLASS assessment of mathematics instruction using mobile eye tracking with expert and novice teachers. *International Journal of Science and Mathematics Education*, 13(2), 389–403.
- Dang, J., King, K. M., & Inzlicht, M. (2020). Why are self-report and behavioral measures weakly correlated? *Trends in Cognitive Sciences*, 24(4), 267–269.
- de Lange, F. P., Heilbron, M., & Kok, P. (2018). How do expectations shape perception? *Trends in Cognitive Sciences*, 22(9), 764–779.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. Retrieved from <http://www.deeplearningbook.org/>.
- Goodwin, C. (1994). Professional vision. *American Anthropologist*, 96(3), 606–633.
- Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, 50(3), 1166–1186.
- Jacobs, V. R. (2017). Complexities in measuring teacher noticing: Commentary. In E. O. Schack, M. H. Fisher, & J. A. Wilhelm (Eds.), *Teacher noticing: Bridging and broadening perspectives, contexts, and frameworks* (pp. 273–279). Berlin: Springer International Publishing.
- 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.
- Jeschke, C., Kuhn, C., Lindmeier, A., Zlatkin-Troitschanskaia, O., Saas, H., & Heinze, A. (2019). Performance assessment to investigate the domain specificity of instructional skills among pre-service and in-service teachers of mathematics and economics. *British Journal of Educational Psychology*, 89(3), 538–550.
- Karsenty, R., & Sherin, M. G. (2017). Video as a catalyst for mathematics teachers' professional growth. *Journal of Mathematics Teacher Education*, 20(5), 409–413.

- Kersting, N. B., Givvin, K. B., Thompson, B., Santagata, R., & Stigler, J. (2012). Developing measures of usable knowledge: Teachers' analyses of mathematics classroom videos predict teaching quality and student learning. *American Educational Research Journal*, 49(3), 568–590. <https://doi.org/10.3102/0002831212437853>.
- Kersting, N. B., Smith, J. E., Vezino, B., Chen, M.-K., Wood, M. B., & Stigler, J. W. (2020). Exploring the affordances of Bayesian networks for modeling usable knowledge and knowledge use in teaching. *ZDM Mathematics Education*, 52, 207–218.
- Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, 133(3), 339–354.
- Nosek, B. A., Hawkins, C. B., & Frazier, R. S. (2011). Implicit social cognition: From measures to mechanisms. *Trends in Cognitive Sciences*, 15(4), 152–159.
- Peterson, M. A., & Salvagio, E. (2008). Inhibitory competition in figure-ground perception: Context and convexity. *Journal of Vision*, 8(16), 1–13.
- Russ, R. S., Sherin, B. L., & Sherin, M. G. (2016). What constitutes teacher learning? In D. Gitomer (Ed.), *Handbook of research on teaching* (pp. 391–438). Washington, DC: AERA.
- Santagata, R., & Guarino, J. (2011). Using video to teach future teachers to learn from teaching. *ZDM International Journal on Mathematics Education*, 43(1), 133–145.
- Santagata, R., & Yeh, C. (2016). The role of perception, interpretation, and decision making in the development of beginning teachers' competence. *ZDM International Journal on Mathematics Education*, 48(1–2), 153–165.
- Scrucca, L., Fop, M., Murphy, T. B., & Raftery, A. E. (2016). mclust 5: Clustering, classification and density estimation using gaussian finite mixture models. *The R Journal*, 8(1), 289–317.
- Sherin, M. G. (2007). The development of teachers' professional vision in video clubs. In R. Goldman, R. Pea, B. Barron, & S. Derry (Eds.), *Video research in the learning sciences* (pp. 383–395). Hillsdale: Lawrence Erlbaum.
- Sherin, B., & Star, J. R. (2011). Reflections on the study of teacher noticing. In M. Sherin, V. Jacobs, & R. Phillips (Eds.), *Mathematics teacher noticing seeing through teachers' eyes* (pp. 66–78). New York: Routledge.
- Sherin, M. G., Jacobs, V. R., & Philipp, R. A. (2011a). Situating the study of teacher noticing. In M. G. Sherin, V. R. Jacobs, & R. A. Philipp (Eds.), *Mathematics teacher noticing seeing through teachers' eyes* (pp. 3–13). New York, NY: Routledge. <https://doi.org/10.4324/9780203832714>.
- Sherin, M. G., Russ, R. S., & Colestock, A. A. (2011b). Accessing mathematics teachers' in-the-moment noticing. In M. Sherin, V. Jacobs, & R. Philipp (Eds.), *Mathematics teacher noticing seeing through teachers' eyes* (pp. 79–94). New York: Routledge.
- Stockero, S. L., & Rupnow, R. L. (2017). Measuring noticing within complex mathematics classroom interactions. *Teacher noticing: Bridging and broadening perspectives, contexts, and frameworks* (pp. 281–301). Berlin: Springer International Publishing.
- 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.
- 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.
- Wolff, C. E., Jarodzka, H., & Boshuizen, H. P. A. (2017). See and tell: Differences between expert and novice teachers' interpretations of problematic classroom management events. *Teaching and Teacher Education*, 66, 295–308.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.