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Learning from (re)experience: What mobile eye-tracking video can help us learn about the cognitive processes of teaching

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Introduction: Classroom teachers need to monitor a group of students varying in interest, knowledge, and behavior at the same time that they present a lesson and adapt it on the fly to student questions and understanding. Many areas of expertise are associated with special kinds of perceptual skills, and teaching presents its own perceptual challenges. We discuss the special nature of the expert looking that teachers must develop and how it relates to more general models of expertise. Standard methods of classroom video are limited in their support of teacher professional looking, and we explore an alternative using mobile eyetracking that overcomes many of these limits. The combination of mobile eyetracking records and standard video enables the participant to "re-experience" a situation in a vivid way, while also seeing things they missed the first time through.

Methods: We report a study in which pairs of novice and experienced teachers teaching the same students watched their own mobile eyetracking recordings while performing a retrospective think-aloud task.

Results: Experienced teachers were better able to describe high-level features and their significance in the lessons, while novices were more likely to talk about in-the-moment events such as things they failed to see while teaching. This is consistent with work on expertise that suggests there are both costs and benefits to expert looking.

Discussion: Our results suggest that the ability to quickly grasp the meaning of a classroom situation may be associated with less awareness of some of the lower-level features on which those inferences are based. Novice and experienced teachers notice different things and have different perspectives on classroom processes; understanding the cognitive process of teachers will require combining insights from each. The methods used in this study are quickly becoming less costly and more accessible, and they have a unique role to play in research and in teacher professional development.

KEYWORDS

teacher vision, mobile eye-tracking, expertise, professional development, video, teacher thinking

1 Introduction

A top worry among beginning teachers (Sadler, 2006) is whether or not they will be able to monitor and manage a classroom of children who vary in interest, knowledge, and needs. It's no wonder this is the case, because attending to a classroom of students while simultaneously teaching a coherent lesson and making on-the-fly adjustments to support student learning is one of the more daunting tasks humans can engage in. This paper will describe some of the special features of teacher looking while teaching, the extent to which current models of expertise describe how proficient teacher looking can develop, limits of currently popular methods using classroom video to support teacher learning, and how mobile eye-tracking can partially transcend these limits. A study describing what novice and experienced teachers notice when watching their own looking patterns as they taught will be presented. The methods described in this paper are increasingly accessible, and we argue that they have a special role to play in both professional development and research on teaching.

1.1 Expert looking as a key feature of teacher expertise

Teaching is a complex activity that involves simultaneously managing relationships among the teacher, the students, and the content that is being taught (Lampert, 2001; Ball and Forzani, 2007). In order to manage a relationship, one must attend to it, and this realization has led to a growing body of research on the role of teacher noticing in the development of teaching expertise. A key part of expertise in many domains is the ability to quickly notice the significance of important features and events, although the nature of those features differs by domain.

In a seminal study on the nature of expertise, de Groot (1946/1965) found that chess grandmasters differed from good chess players primarily in the speed with which they could identify meaningful chess configurations. This basic finding has been replicated in many domains of expertise since then. Goodwin (1994) proposed the term "professional vision" for the ways in which communities of practice can be defined by what the practitioners notice. In the context of teaching, mobile eyetracking research (Keller et al., 2022; Keskin et al., 2024) confirms these basic features of expert looking - that experts are better at quickly noticing what's important in a situation while they teach, which enables them to assess alternative teaching "moves". Research in other domains has emphasized the specificity of expert looking, Panchuk and Vickers (2006) reviewed research showing that looking patterns of successful goalies in two superficially similar sports – ice hockey and soccer – differ in ways that correspond to the affordances of shooting on goal in each activity. As an example of the specificity of expert looking, Panchuk and Vickers (2006) reviewed research showing that looking patterns of successful goalies in two superficially similar sports – ice hockey and soccer – differ in ways that correspond to the affordances of shooting on goal in each activity. Vickers (2007) coined the term "quiet eye" for the way in which experts quickly focus on some area of interest for their skill. Implicit in this term is something significant for the research reported here – experts are distinguished as much for what they *don't* notice as for what they do.

Analysis of video of teaching is at the heart of the lesson study approach developed and widely used in Japan (Lewis and Tsuchida, 1998; Stigler and Hiebert, 2009; Fernandez and Yoshida, 2012). Sherin and Jacobs (2011), Van Es and Sherin (2021) have done extensive research on the nature of teacher noticing and how to develop it using discussion and analysis of classroom video. An encouraging study by Kersting et al. (2010) found that teachers' ability to analyze student thinking and the mathematical content in a set of classroom videos predicted learning among their own students.

The basic idea that experts are distinguished by how quickly they can garner important, useful, and useable information from what they see applies to teaching as well as to other domains. But what are distinctive features of expert looking in teaching? As noted at the start of this paper, teaching requires that one simultaneously manage relationships among the teacher, the students, and the content that is being taught, so one would expect expert teachers to be better at seeing the meaning of events that occur in the classroom. An exhaustive list of features of teacher noticing expertise does not yet exist, but we will describe two illustrative examples of ways in which the looking that teachers should differs from the looking that an ordinary competent adult would engage in.

The first of these involves looking where you *don't* expect to find something. If you wanted a book, you would ignore grocery and hardware stores and look for a bookstore or library, whereas a search for a screwdriver would lead to a very different search pattern. A teacher familiar with her class has a good idea of who is likely to know the answer to a question she poses or who is likely to be involved if she spies a disturbance out of the corner of her eye. In the case of searching for a screwdriver, looking where you expect to find something leads to an efficient and effective search. But in the case of a classroom, it could produce clear inequities. If the teacher asks a question and looks automatically at the person most likely to know the answer, she risks not seeing the student who is excited to finally know the answer to a question. Furthermore, her impression of student understanding based on this biased sampling could lead to an overestimate of the class' understanding of what's being taught.

The second problem concerns one of the key ways that monitoring a classroom of students is different from an ordinary dyadic interaction. In these kinds of interpersonal contexts, it is informative for you as well as rewarding to the person you're interacting with if you focus your attention on the person with whom you are talking. Looking around and monitoring others while having a dialog is a distraction that will likely be seen as rude.

But a teacher has responsibility for monitoring the entire class, and this leads to a situation where it may be irresponsible to focus your full attention on a particular student, even when having a dialog with that student. We have some otherwise surprising evidence consistent with this idea. Cortina et al. (2015) coded classroom lessons where the teacher used our mobile eye-tracking device with the CLASS coding system (Pianta et al., 2008), focusing particularly on measures of the quality of feedback the teacher provides individual students. We looked at the distribution of teacher attention to students by calculating a Gini coefficient for teacher looking at individual students. The Gini index (Milanovic, 1997), often used as a measure of economic or social inequality,

compares the observed cumulative frequency of (in this case) looking at individual students in the class to an idealized situation in which each student received the same amount of teacher attention. A high Gini coefficient indicates that there is a high level of inequality in the attention given to different students.

Cortina et al. (2015) found that for novice teachers, there was a significant negative correlation between the Gini coefficient for attention to students and the quality of the feedback given to individual students. In other words, novice teachers who were attending closely to individual students tended not to be attending to others in the class. This correlation was not significant for experienced teachers. With experience, some (but not all) teachers were able to both give high-quality feedback to individual students while also attending to the rest of the class in an equitable way. Novice teachers could either attend to the class as a whole or to the student with whom they were interacting, but were generally unable to do both at the same time.

1.2 Expertise has costs as well as benefits

The performance of experts can seem magical, including the performance of expert teachers who can, apparently effortless, identify stray students who are confused and provide apt and coherent explanations of complex ideas. But it's worth considering as well some of the costs and limitations of expertise. This idea can be traced to Camerer et al. (1989) discussion of the "curse of knowledge" in describing situations where individuals find it hard to ignore information they have when it's irrelevant to an economic decision. Fisher and Keil (2015) termed a related phenomenon "the curse of expertise" – describing situations in which expertise leads people to over-estimate their understanding of topics in their domain of expertise. Lewandowsky and Thomas (2009) provide a good overview of both the costs and benefits of expertise, many of which can be seen as involving trade-offs between efficient processing on important information and lack of flexibility and conscious access to lower-level processes in some situations. Experts can focus on and quickly identify what's important in their area of expertise, which can be due to attending to configurations rather than individual features, automatization of basic processes, and a move from the use of general (but slow) processes of inference to a more perceptual process involving recognition of patterns. Thus one important cost of expertise may be a loss of conscious access to the underlying evidence on which conclusions are based. This may make expert processing more opaque to researchers, but also may lead to inflexibility in situations where the meaning of stimuli change.

Arguing against the idea that teacher expert looking might be brittle is second key concept relevant to the looking of teacher is Hatano and Inagaki (1986) distinction between routine and adaptive expertise. Routine experts (such as workers in a fast food restaurant) can become quick and adept and performing skilled tasks in predictable contexts but are unable to adapt their skill (e.g., to reproduce that meal at home). Adaptive experts work (such as a sushi chef) work in contexts that require them to continuously adapt to changing circumstances. Much of teaching surely is a matter of adaptive expertise, where the problems that students present to instructors vary from lesson to lesson. To the extent that looking at students requires continuous adaptation to the changing features they present, one might expect that expert looking in the domain of teaching would be more difficult to acquire but more flexible in practice.

In the context of teaching, expert teachers should be quick at noticing significant classroom events and identifying ways to respond to them. But this quick and effortless jump to the significance of an event may mean that they are *less* able than novices to describe the information and thought processes that led to those inferences. They may also be less likely to notice small disturbances that are not likely to lead to bigger disruptions. Because novices are puzzling out the meaning of classroom events in real time, we would predict that novices might be better than experts in describing their thought processes. This may interfere with novices' ability to respond to situations in the classroom in a timely fashion, but may make them better informants about their own thinking.

1.3 Why expert looking can be hard to acquire

Ostrom et al. (2007) describe the "panacea trap" in the context of efforts to improve the physical environment. This involves the belief that there is a single solution (e.g., governmental policy, technology, pricing policy) that will solve a complicated problem. The complexity of teaching and the multiple relationships that must be balanced simultaneously means that it is unlikely that improving a single dimension of teaching will lead to great increases in student learning. A teacher might, for example, have excellent understanding of the material to be taught, but lack an understanding of student thinking (what Shulman, 1992 termed "pedagogical content knowledge") that would enable her to explain it clearly to young students. She might have a clear grasp of relevant content and pedagogical content knowledge but still be unable to help her students stay focused on the lesson at hand.

In the case of teacher noticing, a teacher might be skilled at watching and analyzing classroom teaching but be unable to recognize and put into practice that knowledge in the course of teaching. The complexity of teaching expertise makes it difficult to define what an "expert teacher" is (Stigler and Miller, 2018), who note that this is a problem shared with other domains of expertise. In this study, we used groups of participants (student teachers in their last semester of training paired with the "cooperating teachers" who were mentoring them) in the expectation that there would a substantial difference in expertise as well as experience.

1.4 Perspectives on a lesson – mobile eye tracking and the importance of viewpoint

The structure of most classroom video presents an obstacle to seeing classroom processes in a way that will be usable in the course of teaching. Traditional classroom video takes an "observer perspective," which encourages the viewer to focus on watching the teacher. The influential TIMSS video study (Stigler et al., 1999) explicitly instructed their videographers to "assume the perspective

of an ideal student, then point the camera toward that which should be the focus of the idea student at any given time." (p. 35).

There is a potential problem in learning from this kind of video, because it looks so different from what a teacher sees when she is the one teaching a classroom. Does perspective matter? A simple study briefly reported by Neisser (1983) suggests it does. In this study, students were asked to mentally practice throwing darts and were assigned to four conditions that combined whether or not their mental throws were successful or just missed, and whether or not they viewed this from the thrower's or an observer's perspective. Success of mental throws didn't matter, but far more of the students who imagined the thrower's perspective improved when their actual dart-throwing was assessed.

Because any potential teacher has accumulated far more than 10,000 h watching teachers from a student's perspective, they may develop a "pseudo-expertise" that makes this appear to be the natural way to watch a lesson.

Several projects have captured video from a teacher's viewpoint and found evidence that this can provide uniquely meaningful information. Sherin and Sherin (2010) have used two versions of head-mounted video cameras to capture teaching and have found that this supports discussion of "in-the-moment noticing."

One problem with head-mounted cameras is that they may capture too broad a field of vision to make clear what the wearer is watching. The parafoveal region of the eye, where fine detail can be seen, is limited to approximate 2.5 degrees, which is a very small window into a scene. Mobile eye-tracking methods provide a way to overcome these limitations, by collecting video from the perspective of the teacher while showing where she is looking at a given moment. They do this by combining two camera views, a forward-looking "Cyclopean" view of the scene in front of the teacher (as used by Sherin and others) coupled with an inward-looking camera that tracks gaze position based on reflection of infrared light on the pupil. These two views are combined to produce an image of the scene in front of the wearer with their gaze position superimposed within a circle or some other indicator.

Efforts by our group and others to use mobile eye-tracking provide encouragement for the idea that this can provide a more direct and dynamic representation of teacher looking. In addition to looking at where teachers look, mobile eye-tracking records provide a vivid way of stimulating re-experience of the teaching events.

The combination of eye-tracking video records and think aloud protocols provides a way around some of the limitations of think aloud research in education. This provides a potential way of getting around some of think aloud methods. Asking people to describe their thought processes as they perform a complex task (Ericsson and Simon, 1980) can provide insight into thinking. But both thinking and reflecting on it are demanding tasks and are likely to interfere with each other. In the case of teaching, it would not be realistic for someone to attempt to simultaneously both teach and describe what she was thinking. An alternative approach, often term "stimulated retrospective think-aloud" (Guan et al., 2006) or "cued retrospective reporting" (Van Gog et al., 2005) provides a way around this problem by separating the tasks of performing and thinking aloud, asking participants to recall what they are think as they watch a video of the process they engaged in. Mobile eye-tracking records provide a particularly dynamic stimulus for Stimulated Retrospective Think-Aloud, as they show not just what was in the performer's perceptual field but what they were looking at the time.

In addition to our work already described, Wolff et al. (2016) recorded gaze positions of novice and experienced secondary school teachers as they watched and described lesson fragments. Experts focused more attention on relevant information and were less likely to skip areas and events, and they showed a greater focus in their descriptions on events and cognition. An excellent recent study by McIntyre et al. (2022) compared novice and expert teachers looking at both their own and another teacher's classroom video, looking at both eye movements and think-aloud records. They found that viewers had more to say about the teaching of others, and in general perspective differences were larger than differences between experts and novices, although experts were more likely to talk about relationships.

We believe that by augmenting the video records teachers are shown with video that shows a much broader view of the classroom, they will be able to see and discuss not only what they saw but also what they might have failed to see. This may be particularly useful in professional development, but is also a unique source of data for researchers. The question of what the complexity of teaching caused a teacher not to notice, that she can see when watching again is of interest to anyone hoping to understand the complex perceptual and cognitive demands of teaching.

Should we expect that expert teachers will provide more thorough descriptions of their thinking in performing a retrospective think-aloud stimulated by their eye-tracking records? Not necessarily. Recall that the hallmark of expertise is the ability to quickly grasp the meaning of events that occur in the domain in which you are an expert. One way this happens is by proceduralizing some kinds of noticing, so that one quickly attends to the meaning of the situation and not to the cues that led to that inference. To the extent that one is really an expert at noticing important classroom events, one may simultaneously be better at noticing and reporting the meaning of those events and worse at describing the thought processes that led to that conclusion.

2 Materials and methods

2.1 Participants

Participants were 24 pairs of teachers, although we analyzed transcripts of think-aloud protocols from a total of 20 pairs of teachers (two teachers, one experienced and one novice failed to complete the think-aloud task and these pairs were dropped). Each pair consisted of a novice teacher near the end of the teacher certification program at the University of Michigan, along with the experienced classroom "cooperating teacher" who provided her supervision in the classroom. Cooperating teachers were nominated by principals and then reviewed by the teacher education program. Because each pair of teachers was teaching the same subject matter to the same students in the same classroom, many potential sources of variation were controlled within pairs. Both teachers were often present in the classroom when one taught, although the viewing and narration tasks were done individually. Teachers taught a range of ages and subjects, with 12 pairs at the elementary level and 8 at the secondary level.

2.2 Mobile eye-tracking recording

We asked each teacher to teach a regular lesson wearing an ASL mobile eye-tracking system using methods described in Cortina et al. (2015). Because our focus is on these records as stimuli, we refer the reader to that paper for details of the eye-tracking recording. This produced a teacher-perspective video that included a circle superimposed on the visual field showing where the teacher's right pupil was fixated at a given point in time. We also put two stationary video cameras in the classroom and one that was focused on the teacher and followed her as she moved around the classroom.

2.3 Video stimuli for think-aloud task

We then put together a video that showed two side-by-side synchronized images. One consisted of the teacher's fixations superimposed on a teacher-perspective video, while the other showed a stationary high-definition video of the classroom, selected from whichever of the traditional cameras showed the best depiction of what was in front of the teacher at a given point in time. This showed a much broader view of the entire classroom and thus afforded the possibility for the teacher of seeing things in the video that she had not noticed while teaching. We shared this combined video with the teacher in advance to allow them to watch it prior to coming into the lab to discuss it.

2.4 Methodology for think-aloud task

In the lab, we played the combined video presenting both the eye-tracking record and the best external camera view for the teacher while asking them to comment on it. In defining their task, we used the example of "play-by-play" commentary in sports, asking them to describe their in-the-moment thought processes as they taught. This was then recorded and synchronized with the original video as a commentary track. Teacher comments were transcribed and these transcripts form the basis for this paper.

2.5 Coding

Because our approach in this initial study was largely descriptive, we used a process of emergent coding (Miyaoka et al., 2023) to come up with a set of categories that captured what two of the authors noticed when they read a sample of approximately half the transcripts. In general, we were interested in categorizing what teachers reported attending to, which led to these codes: (1) Single students, (2) the Class or multiple students, (3) comments on Teacher Attention or thinking, (4) Self-evaluation (typically discussing something they failed to notice while teaching), and (5) higher-level Interpretive comments (discussion of general strategies or situations that move beyond what was perceived in the moment). One coder coded every statement in each transcript into these categories. A second coder coded a subset of the transcripts and there was very strong inter-rater agreement as calculated by Cohen's kappa ($\kappa = 0.848$).

3 Results

We conducted a series of 2 (Grade level: Elementary, Secondary)°x°2 (Expertise: Student teacher, Experienced teacher) repeated measures ANOVAs with Expertise as a repeated variable (pairing each teacher with their counterpart teaching the same students). Most of the quantitative measures did not show significant differences by either grade level or expertise. There were two exceptions to this pattern. Experienced teachers at both grade levels made significantly more higher-level "interpretive" comments than did novices [$F(1,18) = 42.5$, $p < 0.01$]; this did not vary with or interact with grade level. There was a marginal effect of Expertise effect on self-evaluative comments (where the teacher commented on things missed when she was teaching), with novices tending to make more of these comments than did experts [$F(1,18) = 3.35$, $0.05 < p < 0.10$].

These results were consistent with our impressions in the initial qualitative review of the transcripts. Novice teachers were more likely to give commentaries on their thinking and perception while they taught, along with noticing things they missed at the moment. Experienced teachers were more likely to talk about broader explanatory issues, which we characterized as interpretive comments rather than simply reflecting immediate perception and experience.

To get a better sense of the teacher talk that underlies these differences, we'll quote at some length from a typical novice and experienced teacher. The novice teacher was much more focused on the in-the-moment observing and thinking he was engaged in, and used the broader view from the regular camera to identify important events (such as students leaving their seats) that he didn't notice in the moment, as well as patterns that caused him to focus on certain students:

> "During the lesson I didn't even realize that one student got out of his seat 'cause I was looking down at the overhead projector. And I noticed that a little bit before, um, a little bit previous in the lesson as well. Another student got out of his seat and I was looking down at the overhead projector and I didn't even notice it. And that's pretty amazing to think of that I didn't even notice that someone got out of their seat 'cause I was so focused on the overhead projector.

> And again, I didn't even notice, since I was focusing on one student so much I didn't even notice that some students were getting out of their seats a little bit. . . And it's kind of interesting again that I'm, even with the slates, I'm still focusing on the right side of the room. Like, I'm not even really looking that much to the left side of the room. And then I just focused in on the student who had been answering a lot of questions for the whole lesson. Like, even before I, before, even before ending the question I was very focused in on her."

The example of an experienced teacher illustrates what we meant by talking about a higher-level, "interpretive" focus:

> "I noticed more so than I noticed during class than I've ever have before how much I've changed views and how many different students I focus on throughout the lesson. I, um, I didn't realize that I do that. But now I do. Now I realize that, obviously, and I believe my intention, uh, is to see as many different students as possible. To judge, uh, their facial expressions about whether they're understanding what I'm saying, whether they're comprehending it. And it's not enough to focus on one student to do that because one student may get it, but the student next door may not. And so I like to look around at as many different students as possible. And I don't think I always did that. I believe when I was younger, both as a student and a younger teacher, I believe I oftentimes would focus on a certain point in the room to relax my nerves. Or focus on one student who seemed to be giving me more feedback. And I think now I focus on many different students to judge their comprehension based on their facial expressions and their focus and where their eyes are and things like that."

But there are similarities as well, and both teachers talk about how when they are dealing with technology such as computers, smartboard, and overhead projectors, their attention is focused on getting the tool to work. The experienced teacher talked about how he took that into account, going on to discuss what he expects from students -

> "Right now I'm, uh, getting something ready my computer. So obviously I'm not looking around at the classroom and trying to prepare something on the computer while students discuss things amongst themselves and with me.

> I also look frequently, I notice, at the kids' desks - not just at their faces, but at their desks - um, to see if they're on the right page in their packets. To see, make sure that they're working on things for my class, because students will often times do homework for their next hour while I'm trying to teach. So they're not getting what I'm doing."

The novice teacher noted his attentiveness to classroom technology, but talked about it descriptively, e.g.,

> "Again, I'm looking down for a long time at the overhead projector."

The quantitative analysis of teacher comments is consistent with the idea that novice and experienced teachers are thinking about the events of teaching differently such that experts have more ready access to the meaning of events and novices to the underlying perceptual features that they notice or miss.

4 Discussion

One of the most famous concepts in the perception of expert teachers was Kounin's (1970) "withitness," term for awareness of what's going on the classroom (often described as having "eyes in the back of your head"). Research has been inconsistent in showing a relation between withitness and other classroom variables (Johnston, 1995), with a study by Irving and Martin (1982) finding a significant *negative* correlation between teacher timely noticing of student misbehavior and student achievement. Over time the concept of withitness seems to have evolved into a more anodyne idea that teachers need to be aware of important things that are going in the classroom (e.g., Tångring and Öhman, 2023).

Given the complicated, multidimensional, overlapping nature of classrooms as described by Doyle (1979) and others, it makes sense that developing the ability to notice the important things going on in classroom involves a great dealing of learning *not* to notice events that are less important, as well as proceduralizing the process of going from perception to meaning. Perhaps the most intriguing finding from this work was that experts were *not* better than novices at describing their attention as they teach. This should not have been too much of a surprise, though – experienced teachers become skilled at situation awareness – attending to what's important, quickly figuring out the significance of what they see and determining how to respond to it. One cost of this proficiency may be a concomitant diminishing of awareness of the lower-level cues that lead to this understanding.

This fits with Lewandowsky and Thomas (2009) discussion of the cost and limits of expert looking. The ability to use perceptual-like processes to identify the meaning of configurations of classroom events is a major advantage for a skilled teacher. She need not stop to puzzle out the significance of particular events but can respond quickly and appropriately. This is a limitation, though, for researchers who are interested in understanding the processes of teacher looking. The apotheosis of this in our sample was an experienced teacher who said very little during the process of describing her teaching video, and then ended by saying "It's all common sense." We don't believe that she was uncooperative, but rather was describing a hard-won state in which the meaning of classroom events has become obvious.

This all suggests that understanding teacher in-the-moment cognition in the classroom will require a combination of coding their actual looking behavior as well as how they think about it. These provide non-redundant sources of information. It also suggests that studying novices may be particularly important, because they are working out in real time relations that have become automatic for experts.

At the same time, the opportunity to watch the hybrid video showing what they saw and what they might have seen was seen as valuable by our novice teachers. This suggests that it may have an important role to play in improving the in-the-moment thinking of novice teachers.

Ericsson (2006) argued that the development of expertise in complex domains requires what he termed "deliberate practice," which involves conscious concentration on the skill, the opportunity to vary performance and informative feedback on the results. Attending to the students in a classroom is a daunting task that can easily be lost among the other demands of teaching. The ability to watch mobile eye-tracking records is a way of providing feedback on looking in a real classroom context. Of course, mere time in the classroom or experience need not lead to expertise, and recent research (Muhonen et al., 2021, 2023) is beginning to describe the cognitive models that guide the ways teachers think about their attention while teaching.

It was particularly striking to us how much the novices noticed in this re-viewing of their teaching. Mobile eye-tracking video is very compelling and viewing it allows the novice teacher to watch what she did while relieving the cognitive of load of making decisions about what to say, where to move, who to look at, etc. It thus enables the participant to reflect on their actions and thinking during teaching. A key element of deliberate practice is the ability to try different ways of performing the skill and observe the outcomes. For novices, observations of things that they failed to notice or ways that they might have responded differently is the basis for acting differently in the future (and seeing whether that works better).

The methods used here are still complicated, but we believe they will quickly become more prevalent, inexpensive and easy to use. Sumer et al. (2018) have described promising methods to begin using machine processing of images to code mobile eye-tracking videos, which may dramatically decrease the cost of coding such records. The cost of the equipment has also gotten substantially cheaper as the quality as gone up. Plans for a do-it-yourself mobile eyetracker are available from Pupil Labs (2023), which enable someone with moderate technical skills to build their own mobile eyetracker for less than $500 (plus the cost of a basic Android phone). The recently released VisionPro system from Apple (2024a) provides a way of integrating eyetracking in real and virtual spaces in the same system. Although they have limited access to eyetracking data due to privacy concerns (Apple, 2024b) some rudimentary eyetracking information is available using accessibility options. This could provide the basis for a relatively inexpensive way of creating the kind of video records used here. The Apple system is particularly intriguing, because it is part of an approach they term "spatial computing" that takes into account where the wearer is located and what they are attending to. This opens up possibilities that extend well beyond this study, in which we can think about how participants move as well as what they see.

The ability to visualize the myriad cognitive processes that teachers engage in in the course of classroom instruction is critical to understanding and improving the work of teaching. The results of this study demonstrate both the need for and the complexity of developing a pedagogy for using these materials in teacher professional development, as well as the idea that teacher running commentaries describing their own looking while teaching can provide a limited but unique window into the thinking that underlies skilled teaching and its development.

The limitations of the study include the relatively small sample size as well as the unconstrained nature of the teacher viewing task during the retrospective think aloud. The hybrid video we presented enabled teachers to notice things that they had initially missed, but it also presents a complicated and unfamiliar scene to the viewer. Most importantly, participants in a sense assigned themselves their own task in deciding what to report. That is significant, but we don't know what teachers might have reported if they were given more specific instructions on what to focus on.

The major contributions of this paper are threefold. First, we describe a way of presenting teachers with a hybrid view that shows both what they were attending to and what they *might* have been attending to, and demonstrates that this is a powerful way of eliciting detailed and vivid retrospective reports on the experience of teaching. Second the method our group uses of comparing last-term prospective teachers with the experienced teachers who are mentoring them provides a straightforward way of looking at expertise in the context of real classroom teaching while comparing teachers who are teaching the same subjects to the same students. Third, we identified a shift in focus on what teachers describe with increasing expertise, from a more in-the-moment focus from novices to a higher-level focus on the significance of classroom events with expertise.

The attention of teachers in a classroom is an important factor in instruction, and the methods use here make it more accessible for research and instruction. Continuing technological developments hold out the promise that we can look at the interplay of attention among multiple participants in an educational setting, which in turn can help us understand how teachers can help guide students to pay attention to what is educationally important.

Data availability statement

The raw transcribed data supporting the conclusions of this article will be made available in anonymized form by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the University of Michigan Health Sciences & Behavioral Sciences IRB. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KM: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. CC: Conceptualization, Formal analysis, Methodology, Software, Writing – review & editing. KC: Conceptualization, Formal analysis, Investigation, Writing – review & editing. LP: Investigation, Methodology, Project administration, Supervision, Writing – review & editing. LC: Formal analysis, Investigation, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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