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ORIGINAL RESEARCH

Noticing and weighing alternatives in the reflection of regular classroom teaching: Evidence of expertise using mobile eye-tracking

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Abstract
Instructional videos are widely used to study teachers' professional vision. A new technological development in video research is mobile eye-tracking (MET). It has the potential to provide fine-grained insights into teachers' professional vision in action, but has yet been scarcely employed. We addressed this research gap by using MET video feedback to examine how expert and novice teachers differed in their noticing and weighing of alternative teaching strategies. Expert and novice teachers' lessons were recorded with MET devices. Then, they commented on what they observe while watching their own teaching videos. Using a mixed methods approach, we found that expert and novice teachers did not differ in the number of classroom events they noticed and alternative teaching strategies they mentioned. However, novice teachers were more critical of their own teaching than expert teachers, particularly when they considered alternative teaching strategies. Practical implications for the field of teacher education are discussed.

Keywords Mobile eye-tracking · Expertise · Teacher training · Think-aloud · Professional vision

Teaching is a complex activity. Teachers typically act under time pressure to make instructional decisions in often ambiguous situations, for example, reacting quickly to student misbehavior (Wahl, 1991). Thus, important aspects of a teacher's expertise are knowing what to be sensitive for in the classroom and how to interpret information, as well as to make instructional decisions based on these interpretations swiftly (Borko et al., 2011; Gaudin & Chaliès, 2015; Jacobs et al., 2010; Kersting et al., 2012; van Es & Sherin, 2008).

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These instructional decisions include decisions about features of a lesson that should be maintained and features that should be changed in the future, that is, generating teaching alternatives (van Es & Sherin, 2002). Researchers refer to these competencies also as teachers' professional vision (Goodwin, 1994; Seidel & Stürmer, 2014).

Acquiring professional vision is critical for novice teachers. One of the main concerns of novice teachers is whether they will be able to monitor and manage a classroom (Sadler, 2006). Research shows that teachers' professional vision can be examined and developed through studying video records of teachers' own classroom teaching (Kleinknecht & Schneider, 2013; Seidel et al., 2011). There has also been increasing research on the role of the video perspective in teachers' learning and reflection processes related to professional vision (e.g., Cortina et al., 2018; Theelen et al., 2019). Recent research indicates that mobile eye-tracking (MET) video footage might be a valuable tool for research on teachers' professional vision in action as well as for teacher training and development, but has yet been scarcely employed (e.g., Cortina et al., 2018).

The goal of the present study was to use MET video footage in combination with think-a-loud protocols to examine differences in expert and novice teachers' reflection of their regular classroom teaching. Understanding how expert and novice teachers differ in their noticing of classroom events and how they reason about alternatives using this novel technology could be instrumental for the design of teacher education and professional development.

Teachers' professional vision: Noticing and the generation of alternative teaching strategies

The concept of professional vision was first developed by Charles Goodwin and describes "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (Goodwin, 1994, p. 606). In research on teaching and teacher education, professional vision has been defined as consisting of two distinct subprocesses: selective attention or noticing and knowledge-based reasoning (Sherin, 2007). *Noticing* refers to the ability of teachers to direct their attention to relevant events in the classroom (Sherin, 2007; van Es & Sherin, 2002) and is considered a prerequisite for the ability to act adaptively in classroom situations (Berliner, 2001; Kersting et al., 2012; Sherin & van Es, 2009; Weber et al., 2018). The way teachers direct their attention affects their reasoning, which in turn influences further noticing processes (Bromme, 1992; Endsley, 1995; van Es & Sherin, 2002).

Knowledge-based reasoning describes teachers' cognitive processing of instructional events based on their knowledge about teaching and learning (Borko, 2004; Seidel et al., 2013; Sherin, 2007; van Es & Sherin, 2002). Knowledge-based reasoning comprises the description, explanation, and prediction of classroom situations (Seidel & Stürmer, 2014). In the process of knowledge-based reasoning, teachers draw on their knowledge on the subject matter and the classroom context to understand students' actions and reactions and connect what happens in the classroom with broader principles of teaching and learning (Sherin, 2007; van Es & Sherin, 2002).

Generating and weighing alternative teaching strategies is one important aspect of teachers' knowledge-based reasoning (Schwindt, 2008; Seidel et al., 2011). It is assumed that if teachers apply their knowledge, for example, when watching videos of their own or others' instruction, they come up with and weigh alternative teaching strategies in response to the instruction they observed (e.g., Kersting et al., 2010, 2012). These alternative teaching strategies can be expressed as suggestions for improving instruction, but also as explanations of why the chosen teaching strategy has advantages over other strategies mentioned (Santagata et al., 2007).

Generating and weighing alternative teaching strategies is considered particularly important for effective teaching (Kersting et al., 2012; Kleinknecht & Gröschner, 2016; Santagata & Guarino, 2011). For example, there is evidence that generating alternative teaching strategies is positively related to students' learning outcomes. Kersting et al. (2010) showed that more effective teachers in terms of student learning gains over a school year are better at generating alternative teaching strategies than less effective teachers. To be able to weigh alternative teaching strategies, teachers first need to identify a critical classroom event. In a second step, they need to access their knowledge of teaching strategies to infer that a different strategy would be advantageous or disadvantageous (Santagata & Guarino, 2011). In the present study, we focus on these two important aspects of teachers' professional vision: noticing of classroom events and weighing alternative teaching strategies.

Professional vision and expertise

A widely used tool for studying teachers' professional vision is classroom video (Brophy, 2004; Gaudin & Chaliès, 2015; Goldman et al., 2007). Research on video clubs in teacher professional development—initially stimulated by Sherin and van Es (2005)—has shown that teachers can develop their teaching competencies and professional vision by continuously and collaboratively studying video records of their own or other teachers' instructional videos (e.g., Kleinknecht & Schneider, 2013; Seidel et al., 2011). It is assumed that teachers improve their awareness of students' learning processes during classroom instruction through noticing relevant events in the video footage and reasoning about them (Sherin & van Es, 2005).

Research that used teachers' own or other teachers' teaching videos also provided evidence for differences in expert and novice teachers' professional vision. Seidel and Prenzel (2008) emphasize that expert teachers (with mostly more than five years of teaching experience) outperformed students in teacher training in their knowledge-based reasoning when viewing authentic classroom videos in standardized assessments. Copeland et al. (1994) let expert and novice teachers watch a video that showed typical interactions between a teacher and students. Experienced teachers, in contrast to novice teachers, saw connections between classroom events and suggested alternative courses of action. In this study, expert teachers were identified based on their extensive teaching experience, their membership in a professional group, and their performance, whereas novice teachers were inexperienced and experienced students in teacher training programs, that is, undergraduate students enrolled in a "preprofessional" teacher program and postgraduate students at the end of a one-year elementary credential program about to start their careers as teachers. In a more recent study by Schäfer and Seidel (2015), participants watched a video in which two pedagogical strategies that were relevant for student learning could be noticed and reasoned on. The results indicated that pre-service teachers struggled to link a noticed classroom event to general pedagogical concepts and their reasoning regarding those classroom events hardly matched experts' interpretation of the same events. The experts in this study were professionals in the field of teaching and learning with 5 to 10 years of experience in teacher education and systematic classroom observation.

In addition, research shows that expert teachers (i.e., teachers with at least 5 years of teaching experience) seem to construct richer and more meaningful representations of classroom events and focus more strongly on students' learning than novice teachers do (i.e., students in teacher training or first year classroom teachers; Sabers et al., 1991; Wolff et al., 2015). This was evident, for example, in the fact that expert teachers, as opposed to novice teachers, were able to make predictions about classroom management events and proposed more alternative teaching strategies after viewing several teaching video fragments of a novice teacher, indicating richer knowledge and a deeper understanding of what is happening in the classroom (Wolff et al., 2015).

These differences between expert and novice teachers have been attributed to expert teachers' more elaborated and coherently organized knowledge structures (Borko & Livingston, 1989; Colton & Sparks-Langer, 1993; Leinhardt & Greeno, 1986; Pauli & Reusser, 2003; Putnam, 1987). It is assumed that these so called "schemata" or "curriculum scripts" enable teachers to rapidly identify meaningful patterns in the classroom and to make informed and flexible instructional decisions (Colton & Sparks-Langer, 1993; Putnam, 1987; see also Lachner et al., 2016 and Wolff et al., 2021).

The ability to notice relevant events (i.e., professional vision) is directly linked to a person's visual perception. Research has shown that expert and novice teachers differ in their ability to notice relevant events in the classroom (Miller, 2011; Berliner, 2001; Ericsson, 2018; Gegenfurtner et al., 2011). Cognitive psychology uses phenomena such as situational awareness (Endsley, 1995) and cognitive tunneling (Dirkin, 1983) to describe the difference in perception of experts and novices. Situational awareness is defined as comprising three factors: (a) perception of meaningful elements in an environment, (b) comprehension of their meaning, and (c) projection of their status in the near future (Endsley, 1995; see also Miller, 2011). Situational awareness in the classroom could imply, for example, that the teacher notices that a group of students are chatting in the back of the class (perception), realizes that they are not paying attention to the lesson, which disturbs the lesson and could reduce the students' learning (comprehension), and decides to change his or her position and stand close to the group to stop the distraction (projection). In contrast, cognitive tunneling refers to novices narrowing their attentional field when performing a complex task (Dirkin, 1983). In the classroom context, this could happen, for example, when a novice teacher gives feedback to a particular student and stops paying attention to the rest of the class. Overall, it is assumed that the viewing patterns of experts are attuned to the demands of the situation and thus help to maintain situational awareness, whereas the viewing patterns of novices show less optimal selection from the complexity of the perceptual world (Miller, 2011).

Eye-tracking technology has been used for quite some time to study the visual behavior of experts and novices in a variety of fields (Reingold & Sheridan, 2011) and has more recently been discovered for teaching as well (Beach & McConnel, 2019; Jarodzka et al., 2017). The major advantage of eye-tracking technology is that it can be used to shed light on humans' initial cognitive information processing (i.e., visual intake, integration, and active search for information; Jarodzka et al., 2021).

Eye-tracking studies indicated that there is evidence of expertise in teachers' visual behavior. For example, studies showed that expert teachers (i.e., recognized teachers with more than seven years of teaching experience) fixated on more areas, revisited them, and had more fixations on areas where relevant information was available (i.e., areas showing students and classroom activity) than novice teachers (i.e., students in teacher training), whereas novice teachers tended to skip areas in their visual field (Wolff et al., 2016). Furthermore, students in teacher training failed more often to identify relevant classroom events in standardized video sequences and consequently missed the cues for teacher action, whereas recognized teachers with at least 10 years of teaching experience paid attention to the event while simultaneously maintaining a broad overview of the classroom (van den Bogert et al., 2014; see also Wyss et al., 2021). In addition, expert teachers needed less time to comprehend the event as they had shorter fixation durations than novice teachers when a classroom event occurred (van den Bogert et al., 2014). Using MET technology, Cortina et al., (2015) found that first year classroom teachers who were rated as being highly responsive to individual students were less able to divide their attention evenly across the whole class, whereas experienced teachers did not show this trade-off: They managed to be both responsive to individual students and attentive to the whole class.

However, an eye-tracking study that examined the professional vision of experienced physical education teachers with at least five years of teaching experience compared to that of first- and last-year students in teacher training found that the professional vision of experienced teachers and last-year students was equally developed and only less developed in first-year students. Commenting on 12 slides from a gymnastics lesson after viewing them for a few seconds, the three groups did not differ in the number of events reported or in the number and duration of the fixations. But last-year students and experienced teachers correctly reported more critical events (e.g., student misbehavior or the teacher giving a poor demonstration) than first-year students did (Behets, 1996).

In sum, eye-tracking and video studies in the field of expertise research provide evidence that experts rather than novices are able to rapidly perceive relevant classroom events and ignore unimportant events, while at the same time paying attention to the whole classroom. This is also reflected in their eye movements. Further, experts are better able to link classroom events to their experience and knowledge, are more likely to suggest alternative teaching strategies when reflecting on lessons, and to make predictions about subsequent classroom events.

Importantly, although MET video provides the opportunity to evaluate teachers' professional vision in their gaze patterns, the present study focuses on analyzing teachers' professional vision expressed in their reflections on their MET videos rather than in their eye-tracking metrics. Eye-tracking is used in this study to illustrate the eye movements of experts and novices in their teaching videos.

Effects of different types of classroom videos on the assessment of teachers' professional vision

Different types of classroom video are used to investigate teachers' professional vision, differing in the perspective (i.e., filming from the student perspective or the teacher perspective; e.g., Borko et al., 2008; Snoeyink, 2010), agency (i.e., filming the teacher's own lesson or the lesson of another teacher; e.g., Gold et al., 2020; Krammer et al., 2006; Zhang et al., 2011), as well as in the technology used (e.g., stationary video, 360° cameras with virtual reality, or MET; e.g., Cortina et al., 2018; Theelen et al., 2019).

The use of teachers' own versus others' classroom videos

Whether to use teachers' own teaching videos or recordings of other teachers depends on the learning goals (Blomberg et al., 2014). A video of other teachers is considered helpful for developing a critical stance toward instruction, whereas self-recordings give teachers the opportunity to critically reflect and hone their own skill sets (Gaudin & Chaliès, 2015; Seidel et al., 2011). Empirical evidence supports the notion that self-video compared to other-teacher video increases pre-service and in-service teachers' sense of authenticity in the professional learning process that is perceived as motivating (Borko et al., 2008; Brouwer, 2012; Kleinknecht & Schneider, 2013; Rosaen et al., 2008; Seidel et al., 2011).

However, studies also demonstrated that in-service teachers tend to comment less critically, reflect on events less profoundly, and identify fewer alternative teaching strategies when watching stationary videos of their own teaching than when watching other-video (Kleinknecht & Poschinski, 2014; Kleinknecht & Schneider, 2013; Seidel et al., 2011). Seidel et al. (2011) illustrate that teachers who watched their own teaching might be more prone to apply self-protection mechanisms that impair their critical reflection and articulation than teachers who watch other-video. In addition, Kleinknecht and Schneider (2013) suggested that teachers who reflect on their own videos may be less able to develop alternative teaching strategies than teachers who reflect on videos of other teachers because they are too accustomed to their own teaching practices. Furthermore, two studies reported that teachers who saw and reflected on their own teaching practices reported less negative (i.e., disappointment with teaching actions) and more positive emotions (e.g., enjoyment, interest, well-being) than teachers who saw and reflected on other-video (Kleinknecht & Poschinski, 2014; Kleinknecht & Schneider, 2013).

The researchers reasoned that teachers watching their own video might have perceived a discrepancy between their actual teaching practice and their teaching self-concept. The perceived discrepancy might have threatened their teacher identity and induced shame or guilt (see also Tracy & Robins, 2004). As a consequence, teachers could have been less open about their emotions to protect their self-worth (Kleinknecht & Poschinski, 2014; Kleinknecht & Schneider, 2013). To conclude, previous studies indicated that reflecting on their own videos potentially impairs teachers' reflexive learning processes in video-based interventions. However, these studies did not examine the effect of teacher expertise.

Advantages of MET versus other video technology

MET technology could be a viable solution to this problem as it can be used to assess aspects of pre-service teachers' and in-service teachers' perception and cognition that are not accessible to conscious thought (Gaudin & Chaliès, 2015). MET measures what direction teachers look in the classroom and what their gaze is focused on. Teachers usually wear the measuring device (i.e., the eye-tracker) as a pair of glasses which allows them to move freely through the classroom. Video footage of the precise focus of a teacher's attention make studying teachers' situational awareness and thought processes during teaching very feasible (Cortina et al., 2015, 2018), which is often difficult in other video formats (e.g., stationary video footage; Brophy, 2004; Shepherd & Hannafin, 2008).

In contrast to the video formats predominantly used in teacher education and teacher professional development, MET video footage has also the advantage that it rarely shows the teachers themselves. MET hence allows teachers to "re-live" their teaching from their own viewpoint instead from the perspective of a classroom observer (Stigler & Miller, 2018). For example, there is evidence that viewing their own MET videos after instruction facilitates a shift in perspective such that teachers focused substantially more on the students and less on themselves in spontaneous think-aloud commentaries (Cortina et al., 2018).

Today's MET technology has evolved over the last 20 years to the point that the teacher now can move around fully unencumbered by the equipment; even the students quickly ignore the device, as it looks very similar to regular glasses (Stigler & Miller, 2018). According to participating teachers, the impairment of the lessons due to MET technology is minimal (Miller, 2011). Thus, MET has the potential to provide insight into teachers' professional vision *in action* (Cortina et al., 2015). However, there are only a few studies that have used MET to study professional vision in teacher education and teacher professional development (see for example, Cortina et al., 2015, 2017, 2018).

The present study

The present study addresses the research gap outlined above by examining differences in expert and novice teachers' professional vision using MET video feedback. Expert and novice teachers' professional vision is examined based on the commentary on their own MET videos. The main goal of this study was to further our understanding of the difference in expert and novice teachers' noticing and weighing of alternative teaching strategies when reflecting on their own teaching using MET video feedback. The following research questions are addressed:

(1) What differences can be found in expert and novice teachers' noticing when reflecting on their own MET video footage?

Based on the theoretical assumption of expert teachers' superior knowledge organization in curriculum scripts (Putnam, 1987; Wolff et al., 2021) and previous empirical research findings (e.g., van den Bogert et al., 2014; Wolff et al., 2015; Wyss et al., 2021), we predicted that expert teachers would notice more classroom events than novice teachers (Hypothesis 1). That is, we expect that when expert teachers watch and comment on their MET teaching videos, they are more likely than novices to report that they discovered something relevant to them in the video.

Furthermore, we explored whether expert and novice teachers differ in how they perceive the events they noticed (i.e., whether they perceived the noticed classroom event as negative, positive, or neutral).

(2) What differences can be found in expert and novice teachers' weighing of alternative teaching strategies when reflecting on their own MET video footage?

Based on previous findings on expert teachers' superior knowledge-based reasoning compared to novices (e.g., Copeland et al., 1994; Wolff et al., 2015), we expected that expert teachers would suggest more alternative teaching strategies than novice teachers when reflecting on their own MET video footage (Hypothesis 2).

Furthermore, expert and novice teachers may mention alternative teaching strategies for different reasons in their reflection process. Either they might mention them because they recognize that an alternative course of action would have been better in a particular teaching situation, they might mention alternative teaching strategies neutrally as part of their reflection process, or they might mention alternative courses of action to explain why their actions were in their eyes superior compared to alternatives. This distinction in terms of weighing alternative courses of action has not yet been investigated and will be explored in the present study.

Method

Sample

The present study is based on a subsample of a larger MET study in which 52 classroom teachers from 26 schools participated (see Cortina et al., 2015). The schools were located in southeast Michigan, United States, and included schools in affluent as well as economically challenged neighborhoods. Half of the participants were experienced teachers; the other half were student teachers who had recently completed their university teacher training. The experienced teachers served as mentors to the student teachers during the academic year. Mentors and mentees taught the same class on separate occasions. Among these 52 classroom teachers, 45 teachers volunteered to participate in an additional meeting with the research team to watch their MET recording, 40 teachers approved using the tape recordings of this session for further anonymous analyses. Three of those recordings could not be used for the current study (low battery of the recording device, microphone covered by clothing that muffled the recording, device failure for the MET recording). There is no association between data missing and expertise status and other demographics. In total, data from 37 classroom teachers could be included in this study (see Table 1 for sample and teacher characteristics). Experienced teachers had, on average, 10.7 years more teaching experience (varying between 4 and 25 years) than the novice teachers. Although years of experience alone do not necessarily translate into being an expert teacher, research indicates that it takes between 4.5 and 7 years of teaching experience to develop expertise as a teacher (Berliner, 2004). Teachers taught students in grades 1 to 11 in 16 different elementary, middle, and high schools. Participation in the study was uncompensated.

Equipment

Teachers wore the ASL Mobile Eye Tracker, a completely self-contained eye-tracking system (ASL mobile Eye, version 2009: https://www.asleyetracking.com). The system consisted of a pair of glasses containing infrared recording device for the eye-tracking and a small digital camera that captured the teacher's field of vision (optics: 640 × 480 px, fixed

Table 1 Sample and teacher characteristics reported separately for experts and novices and for the total sample

Sample and teacher characteristics	Novices	Experts	Total sample
N	19	18	37
Gender (female, in %)	73.7	61.1	67.6
Minority status (in %)	10.5	11.1	10.8
Subjects taught (in %)			
Mathematics	52.6	55.6	54.1
English language arts	21.1	22.2	21.6
Social studies	15.8	16.7	16.2
History	10.5	5.6	8.1

focal range, alternate 30 Hz recording). As shown in Fig. 1, the MET device recorded the teacher's field of view and fixation in the classroom (depicted by the circle). A cable transmitted the data to a recording unit that the teacher wore in a fanny pack around the hips. Two minutes prior to the lesson, a 5-point system calibration was performed in 5–10-m distance. Two stationary cameras provided additional video footage.

Procedure

For each participating teacher, a regular class period was recorded (ranging from 35 to 55 min). Two to ten days after the recordings (depending on teacher availability), expert and novice teachers were asked to freely comment while watching their own MET videos in the research lab using video-stimulated recall (Calderhead, 1981). The recording consisted of the footage of the visual field camera and a superimposed moving red circle indicating the fixation point. Occasionally, the recording started later into the lesson or stopped earlier due to technical issues during recording. A trained research assistant supported teachers' think-aloud process, but was instructed not to make any directive comments. This was facilitated by the seating arrangement (assistant sat behind the teacher) and the use of headphones. Support was sometimes necessary when teachers did not express their thoughts spontaneously at the beginning of the session (e.g., the research assistant asked generic questions such as "So, what's going on right now?" or reminded them of the instruction to freely articulate what is going through their minds). The think-aloud protocols were recorded, transcribed verbatim, and analyzed using qualitative content analysis (Braun & Clarke, 2006).

For the content analysis, we developed a two-dimensional, disjunct category system (Table 2) that included teachers' noticing ("Noticing") and their weighing of alternative teaching strategies ("Alternatives"). For the coding, clauses were the defining unit. Every clause was rated on the respective categories. In the first step of the coding process, coders decided whether teachers noticed a relevant classroom event and/or proposed an alternative teaching strategy in their statements that went beyond what the teachers said they

Fig. 1 Still shot from a MET video commented on by a teacher in the present study. The circle indicates the fixation of the teacher in the classroom

Table 2 Category system for content analysis

Dimension	Valence	Indicator	Example	Explanation
Noticing	Negative	The teacher negatively notices a classroom event	"I didn't notice at all, this group totally goofing off, I guess, at the time I was teaching." (teacher #2)	In this example, the teacher notices student misbehavior in the classroom when watching the MET video that the teacher did not notice when he or she taught the class
	Positive	The teacher positively notices a classroom event	"I think I looked around a lot because there were a lot of participants in this activity, and I wanted to pick the ones who like didn't participate much because it was a fairly easy like addition subtraction activity." (teacher #11)	While watching the MET video, the teacher notices a positive teaching strategy: when he or she assigned an easy task, the teacher tried to engage those students who had not previously participated in the lesson
	Neutral	The teacher notices a classroom event and comments on it in a neutral way (i.e., neither negative nor positive)	"Don't know why I looked just straight right there; I wonder if someone was at the door. Oh, I was looking at the flag, that's it." (teacher #15)	In this example, the teacher notices that he or she is fixating on something specific in the classroom with his/her eyes, but the fixation is not related to a positive or negative classroom event
Alternatives	Negative	The teacher mentions an alternative teaching strategy and indicates that this would be a better alternative compared with his or her teaching	"And I didn't even think about the grouping much ahead of time, but there's several students who probably shouldn't be working together. And it would have been better to place them with someone else." (teacher #2)	The teacher explains that a better teaching strategy would have been to have thought about the seating arrangement in the classroom beforehand
	Positive	The teacher mentions an alternative teaching strategy but indicates that this would be a worse alternative to his or her teaching	"The reason I didn't let <Name> write the sentences is because I knew these were getting progressively harder, and the next problem he's going to do he doesn't understand, so sometimes he gets ahead of himself." (teacher #2)	In this example, the teacher explains that selecting this particular student would have been a worse alternative teaching strategy, because he or she predicted that the student would have failed in front of the class
	Neutral	The teacher mentions an alternative teaching strategy without judging his or her own teaching in the situation (i.e., the teacher does not perceive the strategy as better or worse than his or her actual strategy)	"Sometimes it's better to give them time to explore before you start, which I didn't do this time." (teacher #2)	The teacher only mentions that giving students more time to explore can be an alternative teaching strategy, but does not state that in this particular teaching situation it would have been better or worse to use it

actually used with their students in the classroom videos. In a second step, for the category "Noticing", the coders rated whether the teachers perceived the noticed classroom event as negative, positive, or neutral. For the category "Alternatives", coders rated the mentioned alternative teaching strategy as negative if the teacher indicated that this would have been a better alternative in the given situation, as positive if the teacher framed it as a worse alternative to their actual teaching, and as neutral if the teacher did not compare it to their actual behavior in class.

The transcripts were coded by the first and second author. To measure interrater reliability, assessed by the percentage of agreement, a subsample of 10 transcripts was used. Deviations in the coding were resolved through discussion until consensus was reached. For the dimension "Noticing", the range of the percentage of agreement was between 74.6 and 97.4% prior to consensus discussion. For the dimension "Alternatives", the percentage of agreement ranged between 93.8 and 100% before discussion. The remaining 27 transcripts were then coded by the first author only.

Data analysis

We investigated whether experts and novice teachers differed in the number of events noticed and in the number of alternative teaching strategies mentioned using *t*-tests. To examine whether experts and novices differed in the valence of their noticing and weighing of alternative teaching strategies, we applied multinomial loglinear modelling. This approach tests for significant associations between Noticing/Alternatives and Expertise and allowed us to include relevant control variables in the same analysis. Because teachers differed on several characteristics, such as subject taught, grade level taught, minority status, and gender, that might influence teachers' professional vision (e.g., Miller & Zhou 2007; Blomberg et al., 2011; Jarodzka et al., 2021), we controlled for these characteristics by including them as control variables in the analyses.

A loglinear analysis is a direct generalization of the common cross tabulation and its associated χ^2 statistic to more than two categorical variables (Green, 1988). It allows, for example, to test statistically whether the strength of the association between the categorical variables "Noticing" and "Expertise" is moderated by the school subject or by teachers' gender. The goal of loglinear modelling is to identify the most parsimonious model with respect to the number of effects included to reproducing the observed frequencies for all level combinations of the variables. A good model fit is indicated by an insignificant χ^2 statistic. Significance tests for specific effects are based on iterative χ^2 difference tests for a model that compares the expected and observed cell frequencies. If the discrepancy is large, the χ^2 values is large and leads to the rejection of the null hypothesis of the current model and additional effects are included, making the model less parsimonious. The interpretation of effects is based on the crosstabulation of the variables.

We ran separate models for Noticing (three levels: negative, positive vs. neutral) and Alternatives (three levels: negative, positive vs. neutral) in combination with the variables Expertise (two levels: expert vs. novice), Gender (two levels: female vs. male), Minority Status (two levels: white vs. minority status), Subject (Math vs. other), and Grade Level (elementary vs. middle/high school). Note that for Subject, Grade Level, and Minority Status, the originally more differentiated categories had to be simplified to reduce the number of empty cells in the model.

We started for both analyses with a model that contains no interaction effects (i.e., a model that assumes that none of the variables affect the distribution to the three levels of Noticing or Alternatives; Model I), followed by a model with all two-way interaction effects (Model II; Noticing/Alternatives × Subject, Noticing/Alternatives × Grade Level, Noticing/Alternatives × Minority Status, Noticing/Alternatives × Gender, Noticing/Alternatives × Expertise). If this model remained significant, all higher order interactions involving the key variable Expertise were included one at a time to inspect fit improvement. In a last step (Model III), two-way interaction effects were eliminated one at a time to test if this significantly lowered the model fit. The final model (Model IV) is the model with the fewest number of effects necessary to produce an insignificant χ^2 statistic. Then, all significant effects were analyzed separately as cross-tabulations to identify those cells in the frequency table that contribute substantially to the significant effect. For simplicity, the standardized residual (*SR*) is used for this purpose. Deviations of ± 2 *SR* are used for interpretation because, analogous to a *z* value, as indicate of a significant deviation.

Results

Contrary to our expectations, we found that expert and novice teachers did not differ significantly in the number of noticed classroom events ($M_{\text{Diff}} = -0.56$, 95% CI [–14.18, 13.06], $p = .933$; Hypothesis 1) or in the number of teaching alternatives they mentioned ($M_{\text{Diff}} = -1.01$, 95% CI [–5.05, 3.04], $p = .617$; Hypothesis 2) while watching their own MET video footage. However, the loglinear analysis indicated that expert and novice teachers differed in how they perceive the events they noticed (i.e., whether they perceived the noticed classroom event as negative or positive) and why they mentioned alternative teaching strategies (Table 3). Table 3 shows the model testing sequence from the loglinear analysis for Noticing and Alternatives. For both variables, the overall null hypothesis that no effect exists was rejected (significant χ^2 for Model I in both cases). Including all two-way interactions yielded a good model fit (insignificant χ^2) for Noticing and Alternatives (Model II). However, as Models IIIa-e show, none of the two-way interaction effects between Noticing or Alternatives and Subject, Grade Level, Minority Status, and Gender were essential except for Expertise. This means that even after controlling for these variables, Expertise was associated with a difference in the distribution across the three levels of

Table 3 Loglinear model history

Model	Description	Noticing			Alternatives		
		χ^2	*df*	*p*	χ^2	*df*	*p*
I	No main effects	104.3	64	.001	186.4	64	.000
II	All two-way interaction effects	33.9	52	.976	54.2	52	.380
III	II without the effect of…						
a	…Noticing/Alternatives × Subject	34.1	54	.984	55.7	54	.412
b	…Noticing/Alternatives × Grade level	38.1	54	.950	57.5	54	.345
c	…Noticing/Alternatives × Minority status	37.1	54	.961	59.9	54	.270
d	…Noticing/Alternatives × Gender	42.2	54	.879	56.3	54	.390
e	…Noticing/Alternatives × Expertise	70.9	54	.061	101.9	54	.000
IV	IIIe with a/b/c/d removed	48.6	60	.843	71.2	60	.152
IV–I	χ^2-Diff test for effect Noticing/Alternatives × Expertise	55.7	4	.000	74.5	4	.000

Noticing as well as Alternatives. From Model II we can infer that no higher order interaction effects needed to be considered because a two-way interaction model already produced a good fit. The loglinear models suggested that none of the additional control variables needed to be considered for the interpretation of the crosstabs Noticing by Expertise and Alternatives by Expertise.

Novice teachers noticed more negative classroom events (43.6%) than positive classroom events (26.1%), whereas the opposite was true for expert teachers with 18.8% negative and 47% positive commentary (Table 4). As the standardized residuals indicate, there was no difference between expert and novice teachers regarding neutral commentary on noticed classroom events.

Novice teachers mentioned more alternative teaching strategies with which they would improve their own teaching (81.4%), whereas expert teachers mentioned alternative teaching strategies with which they would improve their own teaching (42.7%) and which they consider inferior to their own instruction (41.8%) with about the same frequency (Table 5). Neutral commentary on alternative teaching strategies was as common for novice teachers as it was for expert teachers.

Discussion

Classroom videos have become increasingly popular to study teachers' professional vision (Brophy, 2004; Gaudin & Chaliès, 2015; Goldman et al., 2007). The purpose of this study was to use MET video feedback to examine differences in expert and novice teachers' professional vision. More specifically, we compared expert and novice

Table 4 Crosstabulation noticing by expertise

	Expertise		Total sample
Valence	Novice	Expert	
Negative			
#	142	60	202
%	43.6	18.8	31.3
SR	3.9	−4.0	
Positive			
#	99	150	249
%	30.4	47.0	38.6
SR	−2.4	2.4	
Neutral			
#	85	109	194
%	26.1	34.2	30.1
SR	−1.3	1.3	
Total			
#	326	319	645
%	100	100	100
	$\chi^2=46.6$, $df=2$, $p<.001$		

Table 5 Crosstabulation alternatives by expertise

Valence	Expertise		Total sample
	Novice	Expert	
Negative			
#	79	47	126
%	81.4	42.7	60.9
SR	2.6	−2.4	
Positive			
#	6	46	52
%	6.2	41.8	38.6
SR	−3.7	3.5	
Neutral			
#	12	17	29
%	12.4	15.5	14.0
SR	−0.4	0.4	
Total			
#	97	110	207
%	100	100	100
	$\chi^2 = 39.1$, $df = 2$, $p < .001$		

teachers' noticing and weighing of alternative teaching strategies while reflecting on their own MET video footage.

There are three key findings of the present research. First, overall, our findings point to expertise differences in teachers' professional vision when reflecting on their own MET video footage. These differences in expertise only show in the valence of the comments, but not in their number. This might indicate that the novice teachers in our sample have already gained some professional vision allowing them to identify classroom events that are significant to them with heightened sensitivity (see also Behets, 1996) and to re-interpret the classroom situation and generate alternative courses of action (e.g., Santagata & Guarino, 2011). However, this finding deviates from previous research on teachers' professional vision (e.g., Seidel & Prenzel, 2008; Schäfer & Seidel, 2015; van den Bogert et al., 2014; Wolff et al., 2015; Wyss et al., 2021) which indicated that expert teachers exceeded novice teachers in their noticing and knowledge-based reasoning abilities. However, these studies differ from our study in three ways: (1) they examined expertise effects in standardized teaching situations, (2) they used stationary video recordings, and (3) they used video sequences of other teachers to do this. In contrast, the present study examined expertise effects by asking teachers to reflect on their own authentic teaching videos recorded with MET technology. While the total amount of commentary did not differ between expert and novice teachers, it is likely that there are more critical events that lend themselves to commentary (i.e., noticing of critical events and generating alternative teaching strategies) in the footage of the novice teachers. Based on the analysis of the stationary video recording from the same study, for example, Ebright et al., (2021) found that student misbehavior during class could be identified about 1.5 times as often in the recordings for student teachers compared to the recording when the same class was taught by the experienced teachers. Arguably, many misbehaviors qualify as noticeable events.

Another alternative explanation for our finding that expert and novice teachers did not differ in the number of noticed classroom events could be that novices are less able to distinguish between important and unimportant events than experts. Thus, it is possible that novice teachers noticed a similar number of classroom events when watching their MET videos as experts, but the novices' noticed events were not important, whereas experts only mentioned important classroom events in their reflection of their own teaching. This is supported by previous research that indicated that expert teachers identified relevant classroom events and ignored unimportant events in standardized teaching situations (e.g., Behets, 1996; Carter et al., 1988; van den Bogert et al., 2014; Wolff et al., 2016; Wyss et al., 2021).

To conclude, our findings that expert and novice teachers did not differ in the number of noticed classroom events and generated alternative teaching strategies in their own MET videos does not imply that novice teachers have an equally good professional vision as expert teachers. It is more likely that novice teachers noticed as many classroom events in their teaching as experts because they reported more irrelevant events or that there is simply more happening in novices' teaching that lends itself to (negative) commentary and suggestions for improvement compared with experts' teaching.

Second, the present study extended previous research on teachers' professional vision by investigating expertise differences in the valence of teachers' noticing and weighing of alternative teaching strategies. Regarding noticing, previous studies have focused on the ability of experts and novices to identify critical events in (standardized) classroom situations (e.g., Schäfer & Seidel, 2015; van den Bogert et al., 2014; Wolff et al., 2016; Wyss et al., 2021). However, it is not clear to what extent the quality of teacher noticing differs between experts and novices. The present study tackled this research gap by exploring the extent to which expert and novice teachers differed in their noticing of negative, positive, and neutral aspects when commenting on their own MET videos. Our results showed that novice teachers were more critical of their own teaching practice than expert teachers. Novice teachers noticed more negative than positive aspects in their teaching videos, whereas the opposite was true for expert teachers. That novice teachers noticed more negative classroom events in their MET videos could indicate that there were more critical events to note in novices' lessons than in experts' lessons, as discussed above (Ebright et al., 2021). The finding that expert teachers noticed more positive than negative aspects in their MET videos suggests that experts were more satisfied with their own teaching.

Moreover, our study expands on previous studies that focused on comparing expert and novice teachers' generation of alternative teaching strategies when reflecting on (standardized) classroom situations (i.e., a video or slides of other teachers' lesson; e.g., Copeland et al., 1994; Wolff et al., 2015) by exploring differences in experts' and novices' generation and weighing of alternative teaching strategies when reflecting on their own MET teaching videos. We found that novice teachers were particularly more critical when they considered possible alternative teaching strategies than expert teachers, indicated by the high percentage (over 80%) of alternatives they would have preferred over the behavior they displayed in situations they considered worth reflecting on. Importantly, expert teachers were still often critical of their own teaching behavior as they were dismissing potential instructional alternatives in merely half on the cases. Thus, despite their richer teaching experience, expert teachers were still open to entertaining the idea of optimizing their behavior in specific situations when reflecting on their own MET video footage.

Third, the present study also allows conclusions regarding possible effects of MET video feedback on teachers' noticing and weighing of alternative teaching strategies. We found that MET video directs the attention of the teacher in their self-reflection of their teaching to events that they most likely missed while teaching but noticed in the review process with MET video footage. Furthermore, we showed that both expert and novice teachers were able to reflect on and identify alternatives to their teaching practices when watching their own MET videos. Thus, our results suggest that MET video feedback might help expert and novice teachers to advance their professional vision with regard to their noticing and weighing of alternative teaching strategies. Until now, only one study, which focused on pre-service teachers, suggested that MET video feedback could be fruitful in this endeavor (Stigler & Miller, 2018). Watching their lessons "through their own eyes" with MET video feedback offers teachers a new approach to reflect on their own teaching.

Practical implications

We maintain that MET video feedback holds promise to improve video feedback for novice teachers in various settings. The second author used MET video feedback with great success in a classroom setting with novice teachers who taught regular middle and high school classes. In the think-aloud phase, the instructor listened and took note when a "Noticing" or "Alternative" comment was a candidate for individual or (if the teacher was comfortable with it) group discussion. The MET combined with think-aloud commentary lends itself to a discourse that is led by the novice teachers themselves which help avoiding the instructor to simply impart knowledge about arguable better ways to handle a given situation, alternatives are explored in the discussion and—ideally—also reflected with respect to their feasibility at the actual stage of training. These reflections and discussions allow novice teachers to gradually acquire better strategies for teaching in a process that feels authentically their own without lecture. Of course, in-service teachers could also benefit from such courses in teacher professional development settings. This technique is consistent with the deliberate practice approach in which expertise can be acquired through a goal-oriented, focused, intentional, and structured effort by combining effective teachers, immediate feedback, and opportunity for repetitions and practice (e.g., Ericsson, 2018).

The results of the present study did show, however, that novice teachers' evaluative reflections on their own teaching remained negatively tinted which may require counteractive measures (Sherin & van Es, 2009). Previous research shows that the perception of failure in teaching reduces teachers' self-efficacy (i.e., teachers' belief that they can influence how well students learn, including those who may be difficult or unmotivated; Guskey & Passaro, 1994). A lowered teaching self-efficacy is likely to contribute to teachers' expectation that they will also fail in future teaching situations (Bandura, 1997; Tschannen-Moran & Hoy, 2007). Thus, if MET video feedback is used in teacher education as a tool to self-reflect on prospective teachers' own instruction, it might be advisable to train prospective teachers to also identify the positive aspects of their teaching. For example, providers of feedback could remind novice teachers to also focus on the positive aspects or ask them whether there are different perspectives on the critical classroom situation (Kleinknecht & Gröschner, 2016).

Limitations and future research

Although this study significantly expands the body of knowledge on differences between expert and novice teachers with regard to their noticing and weighing of alternative teaching strategies using modern MET technology, we acknowledge the limitations of our results. For example, the time between the MET recordings and the stimulated recall sessions was not constant between teachers (2–10 days). The varying time span could have an impact on participants' recall and thus on their comments in the think-aloud protocols. It has been discussed in the literature that a delay between an event and the recall of an event leads to a loss in the accuracy of the stimulated recall (e.g., Gass, 2001), but also that it may enhance recall (e.g., Spellman & Bjork, 1992). Note, however, that the recall stimulus (MET footage) is very strong and teachers never reported difficulty remembering the lesson.

Furthermore, it is also worth noticing that the perceived quality of the recorded instruction rated by experts varied and occasionally crossed between expert and novice teachers who were teaching the same class on different occasions (i.e., the quality rating of the novice teacher exceeded the rating for the expert, see Cortina et al., 2015). While we did not find significant interactions with the school subject, grade level, gender, or minority status of the teachers observed, the power of the statistical tests for higher order interactions was low. Those variables all have the potential to moderate the reported expert–novice differences.

Moreover, expert and novice teachers in our sample taught a wide range of grade levels (grades 1–11). Teaching younger and older students inevitably requires different instructional practices. While older students are often able to work rather independently on tasks in class, younger students need more individual attention and guidance from the teacher. In addition, depending on (subject-specific) classroom activities, seating arrangements may also differ between grade levels. For example, carpet seating close to the teacher during book reading is common in grade 1, while this is no longer practiced in higher grades. These differences in instructional practices between grade levels could influence teachers' field of vision as well as the classroom events in general that teachers comment on while watching their MET videos. However, it is important to note that the loglinear analyses showed that the different grade levels taught did not affect the results of this study.

As it is true for field studies in schools in general, it is safe to assume that the classrooms observed were a positive selection with respect to (dis-)functionality of the classroom; teachers of very unruly classroom are less likely to have volunteered to participate in the study.

In terms of future research, it would be useful to extend the current findings by investigating the development of teachers' professional vision and expertise more closely. In the present study, we compared noticing and weighing of alternative teaching strategies in two expertise groups: expert and novice teachers. However, examining expertise development with three or more groups (e.g., first-year students, advanced student teachers, first-year teachers, and expert teachers) could elucidate the role of transitions (i.e., from educational or academic contexts into professional contexts) in expertise development as well as enable researchers to examine nonlinear trajectories of expertise development (Boshuizen et al., 2020; for examples see, Behets, 1996; Boshuizen et al., 1995; Boshuizen & Schmidt, 1992; Carter et al., 1988; Copeland et al., 1994; Sabers et al., 1991).

Conclusion

Using teachers' MET videos of their own teaching, the present study confirmed that expert and novice teachers differed in how they perceived their own instructional practices, reflecting differences in expertise. While expert and novice teachers did not differ in the number of noticed classroom events or generated alternative teaching strategies, differences between expert and novice teachers were apparent in the valence of their commentary. Novices noticed more negative than positive events in their teaching videos, whereas the opposite was true for experts. Furthermore, expert teachers proposed equal numbers of alternative teaching strategies that they perceived as superior and inferior to their own teaching, whereas novices were much more critical towards their teaching practices and explained mainly how they could improve their teaching using a different approach. We conclude that MET video feedback offers a natural way to broaden expert and novice teachers' reflection on their teaching practices.

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Declarations

Conflict of interest We have no conflicts of interest to declare. Data and code are available upon request.

References

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman & Company.

Beach, P., & McConnel, J. (2019). Eye tracking methodology for studying teacher learning: A review of the research. *International Journal of Research & Method in Education, 42*(5), 485–501. https://doi.org/10.1080/1743727X.2018.1496415

Behets, D. (1996). Comparison of visual information processing between preservice students and experienced physical education teachers. *Journal of Teaching in Physical Education, 16*(1), 79–87. https://doi.org/10.1123/jtpe.16.1.79

Berliner, D. C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research, 35*, 463–482. https://doi.org/10.1016/S0883-0355(02)00004-6

Berliner, D. C. (2004). Describing the behavior and documenting the accomplishments of expert teachers. *Bulletin of Science, Technology & Society, 24*(3), 200–212. https://doi.org/10.1177/0270467604265535

Blomberg, G., Stürmer, K., & Seidel, T. (2011). How pre-service teachers observe teaching on video: Effects of viewers' teaching subjects and the subject of the video. *Teaching and Teacher Education, 27*(7), 1131–1140. https://doi.org/10.1016/j.tate.2011.04.008

Blomberg, G., Sherin, M. G., Renkl, A., Glogger, I., & Seidel, T. (2014). Understanding video as a tool for teacher education: Investigating instructional strategies to promote reflection. *Instructional Science, 42*(3), 443–463. https://doi.org/10.1007/s11251-013-9281-6

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3–15. https://doi.org/10.3102/0013189x033008003

Borko, H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. *American Educational Research Journal, 26*(4), 473–498. https://doi.org/10.3102/00028312026004473

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education, 24*(2), 417–436. https://doi.org/10.1016/j.tate.2006.11.012

Borko, H., Koellner, K., Jacobs, J., & Seago, N. (2011). Using video representations of teaching in practice-based professional development programs. *ZDM, 43*(1), 175–187. https://doi.org/10.1007/s11858-010-0302-5

Boshuizen, H. P., & Schmidt, H. G. (1992). On the role of biomedical knowledge in clinical reasoning by experts, intermediates and novices. *Cognitive Science, 16*(2), 153–184. https://doi.org/10.1016/0364-0213(92)90022-M

Boshuizen, H. P. A., Schmidt, H. G., Custers, E. J. F. M., & van de Wiel, M. W. (1995). Knowledge development and restructuring in the domain of medicine: The role of theory and practice. *Learning and Instruction, 5*(4), 269–289. https://doi.org/10.1016/0959-4752(95)00019-4

Boshuizen, H. P., Gruber, H., & Strasser, J. (2020). Knowledge restructuring through case processing: The key to generalise expertise development theory across domains? *Educational Research Review, 29*, 100310. https://doi.org/10.1016/j.edurev.2020.100310

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bromme, R. (1992). *Der Lehrer als Experte: Zur Psychologie des professionellen Wissens [The teacher as expert: The psychology of professional knowledge]*. Huber.

Brophy, J. (2004). *Using video in teacher education*. Elsevier.

Brouwer, C. N. (2012). Self-viewing with structured video guide. In *Paper presented at the annual meeting of the American educational research association*. Vancouver, Canada.

Calderhead, J. (1981). Stimulated recall: A method for research on teaching. *British Journal of Educational Psychology, 51*(2), 211–217. https://doi.org/10.1111/j.2044-8279.1981.tb02474.x

Carter, K., Cushing, K., Sabers, D., Stein, P., & Berliner, D. (1988). Expert–novice differences in perceiving and processing visual classroom information. *Journal of Teacher Education, 39*(3), 25–31. https://doi.org/10.1177/002248718803900306

Colton, A. B., & Sparks-Langer, G. M. (1993). A conceptual framework to guide the development of teacher reflection and decision making. *Journal of Teacher Education, 44*(1), 45–54. https://doi.org/10.1177/0022487193044001007

Copeland, W. D., Birmingham, C., DeMeulle, L., D'Emidio-Caston, M., & Natal, D. (1994). Making meaning in classrooms: An investigation of cognitive processes in aspiring teachers, experienced teachers, and their peers. *American Educational Research Journal, 31*(1), 166–196. https://doi.org/10.3102/00028312031001166

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*, 389–403. https://doi.org/10.1007/s10763-014-9610-5.

Cortina, K. S., Müller, K., Häusler, J., Stürmer, K., Seidel, T., & Miller, K. F. (2018). Feedback mit eigenen Augen: Mobiles Eyetracking in der Lehrerinnen- und Lehrerbildung [Feedback through one's own eyes: Mobile eye tracking in teacher education]. *Beiträge zur Lehrerinnen- und Lehrerbildung*, *36*(2), 208–222. https://doi.org/10.25656/01-17097.

Dirkin, G. R. (1983). Cognitive tunneling: Use of visual information under stress. *Perceptual and Motor Skills, 56*, 191–198. https://doi.org/10.2466/pms.1983.56.1.191

Ebright, B. D., Cortina, K. S., Mahler, N., & Miller, K. F. (2021). *Racial reprimands? Teacher response to student misbehavior – A mobile eye tracking study*. Manuscript submitted for publication

Endsley, M. R. (1995). Measurement of situation awareness in dynamic systems. *Human Factors, 37*(1), 65–84. https://doi.org/10.1518/001872095779049499

Ericsson, K. A. (2018). The differential influence of experience, practice, and deliberate practice on the development of superior individual performance of experts. In K. A. Ericsson, R. R. Hoffman, A. Kozbelt, & A. M. Williams (Eds.), *Cambridge handbooks in psychology. The Cambridge handbook of expertise and expert performance* (pp. 745–769). Cambridge University Press. https://doi.org/10.1017/9781316480748.038

Gass, S. M. (2001). Innovations in second language research methods. *Annual Review of Applied Linguistics, 21*(1), 221–232.

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

Gegenfurtner, A., Lehtinen, E., & Säljö, R. (2011). Expertise differences in the comprehension of visualizations: A meta-analysis of eye-tracking research in professional domains. *Educational Psychology Review, 23*(4), 523–552. https://doi.org/10.1007/s10648-011-9174-7

Gold, B., Pfirrmann, C., & Holodynski, M. (2020). Promoting professional vision of classroom management through different analytic perspectives in video-based learning environments. *Journal of Teacher Education*. https://doi.org/10.1177/0022487120963681

Goldman, R., Pea, R., Barron, B., & Denny, S. J. (2007). *Video research in the learning sciences*. Erlbaum.

Goodwin, C. (1994). Professional vision. *American Anthropologist, New Series, 96*(3), 606–633. https://doi.org/10.1525/aa.1994.96.3.02a00100

Green, J. A. (1988). Loglinear analysis of cross-classified ordinal data: Applications in developmental research. *Child Development, 59*(1), 1–25. https://doi.org/10.2307/1130385

Guskey, T. R., & Passaro, P. D. (1994). Teacher efficacy: A study of construct dimensions. *American Educational Research Journal, 31*(3), 627–643. https://doi.org/10.3102/00028312031003627

Jacobs, V. R., Lamb, L. L., & Philipp, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education, 41*(2), 169–202.

Jarodzka, H., Holmqvist, K., & Gruber, H. (2017). Eye tracking in educational science: Theoretical frameworks and research agendas. *Journal of Eye Movement Research, 10*(1), 1–18. https://doi.org/10.16910/jemr.10.1.3

Jarodzka, H., Skuballa, I., & Gruber, H. (2021). Eye-tracking in educational practice: Investigating visual perception underlying teaching and learning in the classroom. *Educational Psychology Review, 33*, 1–10. https://doi.org/10.1007/s10648-020-09565-7

Kersting, N. B., Givvin, K. B., Sotelo, F. L., & Stigler, J. W. (2010). Teachers' analyses of classroom video predict student learning of mathematics: Further explorations of a novel measure of teacher knowledge. *Journal of Teacher Education, 61*(1–2), 172–181. https://doi.org/10.1177/0022487109347875

Kersting, N. B., Givvin, K. B., Thompson, B. J., Santagata, R., & Stigler, J. W. (2012). Measuring usable knowledge: Teachers' analyses of mathematics classroom videos predict teaching quality and student learning. *American Educational Research Journal, 49*(3), 568–589. https://doi.org/10.3102/0002831212437853

Kleinknecht, M., & Gröschner, A. (2016). Fostering preservice teachers' noticing with structured video feedback: Results of an online-and video-based intervention study. *Teaching and Teacher Education, 59*, 45–56. https://doi.org/10.1016/j.tate.2016.05.020

Kleinknecht, M., & Poschinski, N. (2014). Eigene und fremde Videos in der Lehrerfortbildung. Eine Fallanalyse zu kognitiven und emotionalen Prozessen beim Beobachten zweier unterschiedlicher Videotypen [Own and others' video in teacher professional development: A case study on cognitive and emotional processes during observation of two different video types]. *Zeitschrift Für Pädagogik, 60*(3), 471–490.

Kleinknecht, M., & Schneider, J. (2013). What do teachers think and feel when analyzing videos of themselves and other teachers teaching? *Teaching and Teacher Education, 33*, 13–23. https://doi.org/10.1016/j.tate.2013.02.002

Krammer, K., Ratzka, N., Klieme, E., Lipowsky, F., Pauli, C., & Reusser, K. (2006). Learning with classroom videos: Conception and first results of an online teacher-training program. *ZDM, 38*(5), 422–432. https://doi.org/10.1007/BF02652803

Lachner, A., Jarodzka, H., & Nückles, M. (2016). What makes an expert teacher? Investigating teachers' professional vision and discourse abilities. *Instructional Science, 44*(3), 197–203. https://doi.org/10.1007/s11251-016-9376-y

Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. *Journal of Educational Psychology, 78*(2), 75–95. https://doi.org/10.1037/0022-0663.78.2.75

Miller, K. F. (2011). Situation awareness in teaching: What educators can learn from video-based research in other fields. In M. G. Sherin, V. R. Jacobs & R. A. Philipp (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 51–65). Routledge.

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

Pauli, C., & Reusser, K. (2003). Unterrichtsskripts im schweizerischen und im deutschen Mathematikunterricht [Teaching scripts in Swiss and German mathematics teaching]. *Unterrichtswissenschaft, 31*(3), 238–272.

Putnam, R. T. (1987). Structuring and adjusting content for students: A study of live and simulated tutoring of addition. *American Educational Research Journal, 24*(1), 13–48. https://doi.org/10.3102/00028312024001013

Reingold, E. M., & Sheridan, H. (2011). Eye movements and visual expertise in chess and medicine. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *Oxford handbook on eye movements* (pp. 528–550). Oxford University Press.

Rosaen, C. L., Lundeberg, M. A., Cooper, M., Fritzen, A., & Terpstra, M. (2008). Noticing noticing: How does investigation of video records change how teachers reflect on their experiences? *Journal of Teacher Education, 59*(4), 347–360. https://doi.org/10.1177/0022487108322128

Sabers, D. S., Cushing, K. S., & Berliner, D. C. (1991). Differences among teachers in a task characterized by simultaneity, multidimensional, and immediacy. *American Educational Research Journal, 28*(1), 63–88. https://doi.org/10.3102/00028312028001063

Sadler, T. D. (2006). "I won't last three weeks": Preservice science teachers reflect on their student-teaching experiences. *Journal of Science Teacher Education, 17*(3), 217–241. https://doi.org/10.1007/s10972-005-9004-1

Santagata, R., & Guarino, J. (2011). Using video to teach future teachers to learn from teaching. *ZDM, 43*(1), 133–145. https://doi.org/10.1007/s11858-010-0292-3

Santagata, R., Zannoni, C., & Stigler, J. W. (2007). The role of lesson analysis in pre-service teacher education: An empirical investigation of teacher learning from a virtual video-based field experience. *Journal of Mathematics Teacher Education, 10*(2), 123–140.

Schäfer, S., & Seidel, T. (2015). Noticing and reasoning of teaching and learning components by preservice teachers. *Journal for Educational Research Online, 7*(2), 34–58.

Schwindt, K. (2008). *Lehrpersonen betrachten Unterricht: Kriterien für die kompetente Unterrichtswahrnehmung [Teachers observe instruction: Criteria for competent perception of instruction]*. Waxmann.

Seidel, T., & Prenzel, M. (2008). Wie Lehrpersonen Unterricht wahrnehmen und einschätzen: Erfassung pädagogisch-psychologischer Kompetenzen mit Videosequenzen [How teachers perceive lessons: Assessing educational competencies by means of videos]. In M. Prenzel, I. Gogolin, & H. H. Krüger (Eds.), *Kompetenzdiagnostik*. VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-90865-6_12

Seidel, T., & Stürmer, K. (2014). Modeling and measuring the structure of professional vision in preservice teachers. *American Educational Research Journal, 51*(4), 739–771. https://doi.org/10.3102/0002831214531321

Seidel, T., Stürmer, K., Blomberg, G., Kobarg, M., & Schwindt, K. (2011). Teacher learning from analysis of videotaped classroom situations: Does it make a difference whether teachers observe their own teaching or that of others? *Teaching and Teacher Education, 27*(2), 259–267. https://doi.org/10.1016/j.tate.2010.08.009

Seidel, T., Blomberg, G., & Renkl, A. (2013). Instructional strategies for using video in teacher education. *Teaching and Teacher Education, 34*, 56–65. https://doi.org/10.1016/j.tate.2013.03.004

Shepherd, C. E., & Hannafin, M. J. (2008). Examining preservice teacher inquiry through video-based, formative assessment e-portfolios. *Journal of Computing in Teacher Education, 25*(1), 31–37. https://doi.org/10.1080/10402454.2008.10784606

Sherin, M. G. (2007). The development of teachers' professional vision in video clubs. In R. Goldman, R. Pea, B. Barron, & S. J. Denny (Eds.), *Video research in the learning sciences* (pp. 383–395). Lawrence Erlbaum.

Sherin, M., & van Es, E. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education, 13*, 475–491.

Sherin, M., & van Es, E. A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education, 60*(1), 20–37. https://doi.org/10.1177/0022487108328155

Snoeyink, R. (2010). Using video self-analysis to improve the "withitness" of student teachers. *Journal of Computing in Teacher Education, 26*(3), 101–110. https://doi.org/10.1080/10402454.2010.10784641

Spellman, B. A., & Bjork, R. A. (1992). When predictions create reality: Judgments of learning may alter what they are intended to assess. *Psychological Science, 3*(5), 315–317. https://doi.org/10.1111/j.1467-9280.1992.tb00680.x

Stigler, J. W., & Miller, K. F. (2018). Expertise and expert performance in teaching. In K. A. Ericsson, R. R. Hoffman, A. Kozbelt & A. M. Williams (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 431–452). Cambridge University Press.

Stürmer, K., Seidel, T., Müller, K., Häusler, J., & Cortina, K. S. (2017). What is in the eye of preservice teachers while instructing? An eye-tracking study about attention processes in different teaching situations. *Zeitschrift für Erziehungswissenschaft*, *20*(1), 75–92. https://doi.org/10.1007/s11618-017-0731-9.

Theelen, H., Van den Beemt, A., & den Brok, P. (2019). Using 360-degree videos in teacher education to improve preservice teachers' professional interpersonal vision. *Journal of Computer Assisted Learning, 35*(5), 582–594. https://doi.org/10.1111/jcal.12361

Tracy, J. L., & Robins, R. W. (2004). Keeping the self in self-conscious emotions: Further arguments for a theoretical model. *Psychological Inquiry, 15*(2), 171–177. https://doi.org/10.1207/s15327965pli1502_03

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education, 23*(6), 944–956. https://doi.org/10.1016/j.tate.2006.05.003

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

van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education, 10*(4), 571–596.

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

Wahl, D. (1991). *Handeln unter Druck. Der weite Weg vom Wissen zum Handeln bei Lehrern, Hochschullehrern und Erwachsenenbildnern. [Acting under pressure. The long road from knowledge to action for teachers, university lecturers and adult educators.]*. Deutscher Studien Verlag

Weber, K. E., Gold, B., Prilop, C. N., & Kleinknecht, M. (2018). Promoting pre-service teachers' professional vision of classroom management during practical school training: Effects of a structured online-and video-based self-reflection and feedback intervention. *Teaching and Teacher Education, 76*, 39–49. https://doi.org/10.1016/j.tate.2018.08.008

Wolff, C. E., van den Bogert, N., Jarodzka, H., & Boshuizen, H. P. (2015). Keeping an eye on learning: Differences between expert and novice teachers' representations of classroom management events. *Journal of Teacher Education, 66*(1), 68–85. https://doi.org/10.1177/0022487114549810

Wolff, C. E., Jarodzka, H., van den Bogert, N., & Boshuizen, H. P. (2016). Teacher vision: Expert and novice teachers' perception of problematic classroom management scenes. *Instructional Science, 44*(3), 243–265. https://doi.org/10.1007/s11251-016-9367-z

Wolff, C. E., Jarodzka, H., & Boshuizen, H. P. A. (2021). Classroom management scripts: A theoretical model contrasting expert and novice teachers' knowledge and awareness of classroom events. *Educational Psychology Review, 33*, 131–148. https://doi.org/10.1007/s10648-020-09542-0

Wyss, C., Rosenberger, K., & Buehrer, W. (2021). Student teachers' and teacher educators' professional vision: Findings from an eye tracking study. *Educational Psychology Review, 33*, 91–107. https://doi.org/10.1007/s10648-020-09535-z

Zhang, M., Lundeberg, M., Koehler, M. J., & Eberhardt, J. (2011). Understanding affordances and challenges of three types of video for teacher professional development. *Teaching and Teacher Education, 27*(2), 454–462. https://doi.org/10.1016/j.tate.2010.09.015