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Advancing research on teachers' professional vision: Implementing novel technologies, methods and theories

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Advancing research on teachers' professional vision: Implementing novel technologies, methods and theories

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Table of contents

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Editorial: Advancing research on teachers' professional vision: implementing novel technologies, methods and theories

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Editorial on the Research Topic
Advancing research on teachers' professional vision: implementing novel technologies, methods and theories

The rapidly developing field of technology-enhanced educational research has revolutionized our understanding of teachers' professional vision in the classroom (Keskin et al., 2024; Witt et al., 2024). Over the past decade, the integration of eye tracking technology has gained significant traction, offering profound insights into the cognitive processes underlying teaching. This technology allows researchers to capture and analyze the mechanisms of visual information acquisition, integration and retrieval, shedding light on how teachers interact with their dynamic classroom environment. Eye tracking technology has proven invaluable in revealing how teachers selectively filter and interpret a variety of visual cues. This selective visual perception is fundamental to effective teaching because by focusing on relevant classroom events and quickly ignoring the irrelevant, teachers can make informed, timely decisions that improve student engagement and learning outcomes (Grub et al., 2020).

However, despite these advancements, researchers in the field have identified several limitations in current research (Jarodzka et al., 2020; Kosel et al., 2023; Witt et al., 2024). One major challenge is balancing experimental rigor with the complexity of real classroom environments, as this introduces confounding factors and variability that challenge the consistency of findings. Another issue is that studies are often conducted under varied settings, such as different subjects, age groups, and teaching methods, complicating the generalization of results. Additionally, non-standardized experimental setups and insufficient triangulation of eye tracking data with other data streams, such as think-aloud data, can lead to inconsistent results and reduced validity. Finally, the potential of eye tracking data to foster teachers' professional vision remains largely underexplored. The

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aim of this Research Topic is to address these challenges and expand the scope of research on teachers' professional vision. By leveraging new methodological approaches, such as more advanced strategies for data triangulation and implementing innovative experimental designs, we seek to enhance the robustness and comprehensiveness of this research strand.

Steps toward balancing experimental rigor with the complexity of real classroom environments

Jarodzka et al. investigated the professional vision of pre-service, beginning and experienced teachers by assessing how they perceive and interpret visual cues in classroom management using mobile eye tracking glasses. In this study, $n = 22$ pre-service, $n = 17$ beginning, and $n = 19$ experienced teachers were eye-tracked while teaching their classes. The results revealed no significant differences in the efficiency of visual processing across different teaching experience levels throughout the lesson. Notably, by the end of the lesson, pre-service teachers showed a slight increase in fixation counts compared to the beginning. Although overall teaching experience did not significantly affect the dispersion of fixations, experienced teachers exhibited a broader visual span at the lesson's start than at its end. Additionally, teaching experience did not significantly impact average fixation durations; however, pre-service teachers experienced a slight decrease in fixation durations as the lesson progressed. The key finding of this in-action, mobile eye tracking study is that the authors found an interaction between teaching experience and phase of the lesson, suggesting that all teachers start the lesson in a similar way, but that pre-service teachers in particular seem to experience some sort of classroom management difficulties as the lesson progresses.

Miller et al. focused on noticing skills that classroom teachers need to monitor a group of students varying in interest, knowledge, and behavior while simultaneously presenting a lesson and adapting it on the fly to student questions and understanding. The study discusses that standard methods of classroom video are limited in their support of teacher professional vision, and the authors explore an alternative using mobile eye tracking that overcomes many of these limits. The combination of mobile eye tracking records and standard video enables participants to "re-experience" a situation in an intense way; while also seeing things they missed the first time through. In this study, pairs of $n = 24$ novice and $n = 24$ experienced teachers teaching the same students and then watched their own mobile eye tracking recordings while performing a retrospective think-aloud task. The results showed that 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. One of the study's new findings is that experienced teachers, while quick to grasp the overall meaning of classroom situations, may lack awareness of some lower-level features that inform those inferences. This highlights a potential trade-off in the perceptual processes of expert teachers.

Chaudhuri et al. investigated the association between teachers' physiological and psychological stress and their visual focus of attention, as well as the mediating effect of teaching practices on this association in authentic classroom settings. The study involved $n = 53$ teachers and used multimodal methods: salivary cortisol levels for measuring physiological stress, a self-reported questionnaire for psychological stress, observed teaching practices during one school day, and eye tracking video recordings of classroom teachers during one lesson to assess visual focus of attention. The results showed that neither physiological nor psychological stress was directly related to teachers' visual focus of attention. However, teachers who employed more *student-centered* teaching practices, as opposed to teacher-directed practices, demonstrated a higher number of fixations on students, longer total fixation duration, and a more individualized distribution of visual focus on students. Teaching practices mediated the effect of psychological stress on teachers' fixation counts and distribution of visual focus. The findings suggest that teaching practices influence the visual attention teachers give to students and that teachers' stress affects their visual focus through these practices. These results highlight the importance of providing teachers with training and support to recognize their stress levels and understand how stress can impact their teaching. Enhancing awareness and management of stress, alongside adopting more child-centered teaching practices, can improve teachers' engagement with students.

Improving generalizability through a greater variety of teaching contexts and confounding factors

Stahnke and Friesen explored whether experienced teachers from different secondary school subjects (biology and mathematics) differ in their professional vision of classroom management. The study involved $n = 20$ experienced teachers and used video clips of classroom settings as stimuli. Teachers' eye tracking data and retrospective think-aloud data were recorded and analyzed using quantitative content analysis and epistemic network analysis. The study compared expert teachers' visual attention, their noticing of classroom management events, and their knowledge-based reasoning across both subjects. Results revealed subject-specific differences in professional vision. Experienced biology teachers were more focused on suggesting alternative classroom management strategies, especially those addressing planning aspects such as providing structure and preparing the classroom. Conversely, experienced mathematics teachers were more evaluative in their analysis, concentrating on behavioral management and ensuring student engagement in real-time. These findings highlight the importance of considering subject-specific contexts when studying professional vision in classroom management. Different subjects may require distinct strategies and considerations, influencing how teachers perceive and address classroom management challenges. This study underscores the need for tailored professional development that takes into account the unique demands of different teaching subjects to enhance classroom management skills effectively.

Duvivier et al. explored the visual strategies of $n = 6$ University Supervisor Trainers (UST) for teachers undergoing the Upper Secondary Education Teaching Certification (AESS) in French-speaking Belgium and $n = 16$ pre-service teachers they train. The study aimed to understand how these two groups observe a teaching situation using eye tracking. The video analyzed showed the start of a geography lesson given by a trainee in a primary school class. The results showed that UST and pre-service teachers focus their attention on the same groups of students but do so differently. UST adopt visual strategies distinct from those of pre-service teachers, aligning their approaches with those of expert teachers in other studies using eye tracking. Specifically, UST demonstrated dynamic and floating visual strategies, characterized by more frequent revisits and shorter fixation durations compared to pre-service teachers. Additionally, UST spent less time fixating on very active students compared to pre-service teachers. When analyzing the UST gaze itineraries during the trainee's planning error, both common elements (e.g., teaching tools) and divergent elements (e.g., checking pupils) were observed. This study highlights that UST, compared to pre-service teachers, employ advanced visual strategies that involve dynamic and efficient revisiting patterns and shorter fixation durations, reflecting their expert status. This finding emphasizes the importance of training pre-service teachers to develop similar visual strategies to enhance their observational skills and overall teaching effectiveness.

Keskin et al. investigated whether more negative teacher attitudes and lower teacher recognition toward ethnic minority students are reflected in teacher gaze. The study sought to determine if teachers visually prefer ethnic majority students over ethnic minority students by examining the number of fixations, duration of fixations, and time to first fixation. An explanatory sequential mixed-method design was used with a sample of $n = 83$ pre-service teachers. The pre-service teachers watched a classroom video while their eye movements were recorded and then provided written reflections on their perceptions and related experiences. A standardized survey measured their demographic information, explicit attitudes toward ethnic minority students, self-efficacy for teaching ethnic minority students, and associated stereotypes. Contrary to the hypothesis, the results indicated that pre-service teachers had longer fixation durations on ethnic minority students compared to ethnic majority students. Additionally, positive explicit attitudes toward ethnic minority students were positively correlated with both the number and duration of fixations on ethnic minority students. Qualitative analyses revealed that pre-service teachers linked disadvantaged situations for ethnic minority students to teacher stereotypes and student language difficulties. They also related their reflections to their own experiences as ethnic minorities. These findings suggest that pre-service teachers who hold positive attitudes toward ethnic minority students tend to focus more on them, challenging the notion of visual preference for ethnic majority students. The study underscores the importance of addressing teacher attitudes and biases in teacher education and professional development to better handle student diversity. Further research is needed to explore the implications of these findings for improving equitable attention and recognition in diverse classrooms.

Optimized data triangulation methods

Biermann et al. focused on teachers' noticing as a fundamental precondition for effective teaching by targeting the ability to focus on relevant events in the classroom while ignoring the irrelevant. Many recent studies have utilized eye tracking technology in classroom observations to capture the continuous attentional processes of teachers. Despite the general validity of the eye–mind assumption, this study underscores the necessity of methodological triangulation to accurately determine the focus of attention and its underlying reasons. While previous studies have utilized different data sources like gaze and verbal data, these were often analyzed separately rather than in combination. In this study, verbal data (retrospective think-aloud; RTA) and a reaction-based concurrent measure (keystroke) were collected to assess the noticing process of $n = 34$ novice and $n = 37$ experienced teachers as they watched staged classroom videos. For direct triangulation, these data were combined with eye tracking parameters that indicate attentional processes, such as fixation count, average fixation duration, and revisits. The findings revealed that participants who detected critical incidents in the videos—either through keystroke or RTA—exhibited a higher number of fixations and more revisits to the relevant areas, but their average fixation duration was comparable. However, no significant expertise differences in accuracy were found between novice and experienced teachers. One of the study's strengths is its innovative approach to integrating multiple measures to assess the noticing process, which offers a more comprehensive understanding than eye-movement data alone. Despite only partially significant results, the study demonstrates the potential of combining RTA and keystroke methods to complement and possibly correct eye tracking data.

Wyss et al. examined the professional vision of $n = 31$ pre-service teachers and $n = 32$ in-service teachers by investigating differences in their noticing and reasoning about videotaped classroom events. The study aimed to determine if the groups differed in their observations and interpretations, if the video perspective influenced their noticing and reasoning, and to what extent their gaze behavior differed from their verbal statements. Participants watched an authentic teaching video from different perspectives, and their visual focus of attention was recorded using a remote eye-tracker. Subsequently, participants reported what they had noticed during an interview. The triangulated data revealed that the gaze behavior of pre-service teachers and in-service teachers did not differ, but the content of their verbal statements did. Depending on the video perspective, participants focused on different subjects; however, this difference was not reflected in their verbal reports, indicating an inconsistency between gaze behavior and verbal statements. This finding suggests that pre-service teachers and in-service teachers, while visually focusing on similar elements, interpret and articulate these observations differently. This study highlights the importance of using multiple data sources and types to explore professional vision comprehensively. The inconsistency between gaze behavior and verbal statements underscores the complexity of professional vision and suggests that further research is needed to understand this concept in depth. The results emphasize the need for training that helps pre-service teachers align their visual focus with accurate and meaningful interpretations of classroom events.

Kosel et al. explored how experienced and novice teachers' reason about and diagnose different student characteristic profiles while observing classroom scenes. The profiles included three inconsistent profiles (overestimating, uninterested, and underestimating) and two consistent profiles (strong and struggling). Results indicated that experienced teachers generally achieved higher judgment accuracy in diagnosing student profiles compared to novice teachers. Furthermore, an epistemic network analysis of behavioral cues revealed that experienced teachers made more connections between a broader spectrum of surface cues (e.g., a student's hand-raising behavior) and deep cues (e.g., a student being interested in the subject). This comprehensive and robust reasoning in experienced teachers underscores the impact of professional experience on diagnostic skills. The study demonstrates that epistemic network analysis is a strong method to further analyze teachers' reasoning. The study highlights that experienced teachers' reasoning is not only more accurate but also more integrative, linking both surface and deep cues to form a holistic understanding of student characteristics.

First steps in using eye tracking materials to foster (pre-service) teachers' professional vision

Oellers et al. addressed the challenge of promoting a professional vision of teaching, a key factor in teachers' expertise, by investigating the learning processes involved in acquiring this vision. The study aimed to fill the gap in understanding how teachers develop professional vision through video-based intervention programs, which have traditionally focused on outcome measures rather than the learning processes. The study involved $n = 45$ undergraduate pre-service teachers enrolled in a course focused on classroom management. The course required students to apply their classroom management knowledge to analyze authentic classroom videos. The goal was to identify the variety of individual strategies used by students during their video analyses and to examine the relationship between these strategies and the quality of the students' analyses, as measured by their agreement with expert ratings of the video clips. Using a learning analytical approach, the study gathered process-related data to analyze students' behavioral patterns within a digital learning environment. Cluster analyses were conducted to identify video-based strategies and relate them to the quality of analysis outcomes. The results provided insights into the learning processes, revealing different approaches taken by students in analyzing classroom videos. The study identified clusters indicating meticulous and less meticulous approaches to video analysis and found significant correlations between process and outcome variables. These findings have implications for the design and implementation of video-based assignments aimed at promoting professional vision. They suggest the potential for process-based diagnostics and adaptive learning support to enhance the effectiveness of video-based learning activities in teacher education.

Kaminskienė et al. investigated the role of professional reasoning in teacher professional vision and how video with gaze overlay and heatmaps from a mobile eye tracker can support self-reflection and professional vision development in higher education. $N = 4$ university teachers wore a mobile eye tracker during a lecture segment. The study analyzed their gaze distribution on classroom targets alongside their reflective comments while watching recordings of their own behavior. The results showed that mobile eye tracking data provided valuable feedback on how teachers distributed their attention across different areas in the classroom and between students. Visualization of gaze distribution as heatmaps allowed teachers to reflect on their perceived vs. actual gaze allocation. Many teachers realized discrepancies between their perceptions and the eye-tracker data, prompting deeper reflection on their professional reasoning. This self-reflection encouraged teachers to analyze why they diverted their attention to certain areas and consider opportunities for improvement. The study highlighted that heatmap analysis based on mobile eye-tracker data can be a powerful tool for developing teachers' professional vision. It helps in engaging students through more balanced attention distribution. The findings suggest that incorporating mobile eye-tracker recordings and gaze distribution heatmaps into video-based professional development can significantly enhance teachers' reflective practices and professional growth.

Telgmann and Müller examined the noticing skills of pre-service teachers regarding classroom management during teaching. While previous research has shown positive effects of interventions on teachers' noticing during video observation, this study is among the first to investigate noticing during actual teaching. In this quasi-experimental study, $n = 46$ pre-service teachers participated in a standardized classroom simulation after receiving classroom management training. One group received additional prompting on evidence-based classroom management strategies before and during the simulation, another group received only the training, and a control group received no training. Mobile eye tracking and retrospective video observations were used to assess event-related and global noticing. Event-related noticing was measured by the count and accuracy of noticed classroom management events, while global noticing was assessed through eye movement parameters (visit/fixation counts and durations) on students. The results indicated that training and prompting significantly improved pre-service teachers' event-related noticing, with the experimental groups making fewer target and time errors compared to the control group. However, there were no significant differences in global noticing measures such as fixation and visit count and duration on students. A positive correlation was found between higher noticing accuracy and the share of fixations on students. This study expands upon previous research by using mobile eye tracking to obtain objective measures of teachers' noticing. It highlights the importance of knowledge for teachers' noticing during teaching and takes a significant step toward understanding how pre-service teachers' noticing can be enhanced through classroom management training.

Gabel et al. examined how instructional guidance affects pre-service teachers' visual attention to information relevant for classroom management in classroom videos. This mixed-methods eye tracking study compared three instructional conditions: (1) a specific task instruction before video viewing ($n = 45$),

(2) attention-guiding prompts during video viewing ($n = 45$), and (3) a general task instruction before video viewing as a control group ($n = 45$). Participants viewed two classroom videos and clicked a button whenever they identified situations relevant to classroom management. The study hypothesized that specific task instructions and prompts would better guide visual attention compared to general task instructions, as they provide informational cues to focus on specific dimensions of classroom management. It was also expected that both experimental conditions would activate cognitive schemata, resulting in knowledge-based processing of visual information, with specific task instruction having a similar attention-guiding effect as prompts during video viewing. Measurements were taken at the outcome level (mouse clicks) and the process level (eye tracking). Findings confirmed the hypotheses at the outcome level and partially at the process level regarding participants' gaze relational index. In a disruptive classroom situation, participants in the prompting condition demonstrated better attentional performance, evidenced by a higher number of fixations and shorter time to first fixation on disruptive students. Qualitative analyses revealed that without instructional guidance, pre-service teachers were less likely to identify disruptive situations and more likely to focus on other aspects of classroom management related to the teacher's actions. This study highlights the benefits of attention-guiding instructions in pre-service teacher education, emphasizing the economy of implementation and the salience of classroom situations. Both specific task instructions and prompts can significantly enhance pre-service teachers' ability to identify relevant information in classroom management, supporting the development of their professional vision.

Heinonen et al. investigated how university teachers' (mis)conceptions of teaching and learning relate to their ability to notice and interpret pedagogically significant incidents in the classroom, referred to as their professional vision. They also examined whether short pedagogical training could enhance teachers' conceptual understanding and professional vision. A total of $n = 32$ university teachers participated in the study, completing a teacher conception questionnaire and an eye tracking measurement with a stimulated retrospective recall (SRR) interview, using a pre-test/post-test design. The findings revealed that overall, there was no correlation between professional vision scores and (mis)conceptions of teaching and learning. However, in classroom situations requiring selective visual attention due to simultaneous interactions, teachers with more misconceptions and less sophisticated conceptions focused on the teacher's actions, while those with fewer misconceptions and more sophisticated conceptions focused on students' actions. Pedagogical training was found to improve the sophistication of less sophisticated conceptions of teaching and learning among university teachers. Statistically significant improvements in participants' noticing abilities were identified, though their interpreting skills did not show similar improvements. The study highlights the importance of pedagogical training and the development of conceptual understanding for university teachers. These elements are crucial in supporting their pedagogical expertise and professional vision, particularly in relation to learning theories. Furthermore, the study introduces an innovative approach by combining mobile eye tracking with retrospective think-aloud tasks, providing a richer understanding of the noticing process. The methods used in this study are becoming more cost-effective and accessible, which could revolutionize both research and professional development in teaching.

Collectively, studies in this Research Topic affirm the critical role of eye tracking technology in advancing our understanding of teachers' professional vision. They advocate for a holistic approach that integrates technological, pedagogical, and contextual factors to develop more effective and equitable teaching practices. By addressing the limitations of current research and offering new methodological insights, this Research Topic paves the way for future studies that can further enhance the robustness and applicability of professional vision research in diverse educational settings.

Author contributions

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University teachers' professional vision with respect to their conceptions of teaching and learning: findings from an eye-tracking study

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This study investigated how university teachers' (mis)conceptions of teaching and learning are related to their ability to notice and interpret pedagogically significant incidents in the classroom, that is their professional vision. Additionally, we examined whether university teachers can be supported in their development of conceptual understanding and professional vision through a short pedagogical training. A total of 32 university teachers who participated in this study completed a teacher conception questionnaire and an eye-tracking measurement with a stimulated retrospective recall (SRR) interview. A pre-test/post-test design was utilized. The findings indicate that in general, professional vision scores and (mis) conceptions of teaching and learning did not correlate. However, with regard to classroom incidents where teachers' visual attention needed to be selectively allocated due to simultaneous interactions, university teachers with more misconceptions and less sophisticated conceptions of teaching and learning tended to focus on the teacher's actions in the classroom. By contrast, university teachers with fewer misconceptions and with more sophisticated conceptions of teaching and learning tended to focus on students' actions. University teachers' less sophisticated conceptions became more sophisticated as a result of pedagogical training. Additionally, statistically significant improvements in participants' noticing were identified, but interestingly not in their interpreting skills. The results emphasize the relevance of the need for pedagogical training and the development of conceptual understanding for university teachers in relation to learning theories in order to support their pedagogical expertise as well as their professional vision.

KEYWORDS

professional vision, selective attention, teacher gaze, misconceptions, university teachers, pedagogical expertise, pedagogical training, eye-tracking

1. Introduction

Successful teaching at universities requires that the teacher makes relevant notions in the classroom. Teaching–learning situations at universities are fraught with complex and rapidly changing situations in which university teachers must have an ability to pay attention to events that foster or constrain student learning and simultaneously ignore less important classroom interactions. To guide the limited attentional visual capacity in order to focus on these

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important events requires high-quality pedagogical expertise, including professional vision (Goodwin, 1994). Professional vision means the ability to notice and interpret relevant features of teaching-learning situations to support student learning as effectively as possible (Van Es and Sherin, 2002). Nevertheless, university teachers' pedagogical expertise and professional vision development is still an understudied research area.

University teachers are often experts in their own discipline, but this does not automatically mean that they would be excellent teachers with strong pedagogical understanding. Still today, many university teachers teach without formal pedagogical education and hence have only a limited knowledge of pedagogical concepts and theories (Postareff and Nevgi, 2015). The relation of these potential naïve conceptions and other central elements of teacher expertise, such as professional vision, is a poorly known research area. Previous studies have shown that teachers' beliefs and conceptions related to teaching and learning impact on what and how teachers observe and interpret in classroom situations (Ericsson and Pool, 2016; Meschede et al., 2017; Sun and Zhang, 2022). There have been a number of studies which have focused on university teachers' conceptions of teaching and learning. In summary, the previous research seems to bear out the existence of two broad teaching orientations ranging from focusing on teacher centered activities/content focused approach to interaction with students to foster their learning (e.g., Martin and Balla, 1991; Samuelowicz and Bain, 1992; Gow and Kember, 1993; Trigwell et al., 1994; Virtanen and Lindblom-Ylänne, 2009). Previous studies also show that even university teachers tend to have less sophisticated prior conceptions about teaching and learning and may even harbor misconceptions (Heinonen et al., 2022; Södervik et al., 2022). Thus, attaining a scientific understanding of teaching and learning often requires conceptual change (Vosniadou et al., 2020), and to support university teachers' conceptual change, pedagogical training is needed (Vilppu et al., 2019; Heinonen et al., 2022; Södervik et al., 2022). Compared to primary and secondary education, university teachers often lack pedagogical education, because in many countries pedagogical education is not a prerequisite for working as a university teacher (Murtonen and Vilppu, 2020). This variation in their pedagogical background makes university teachers a special group compared to teachers in lower education levels and highlights the need for research into pedagogical expertise development within the university context. However, little is known about university teachers' professional vision with respect to their (mis)conceptions of teaching and learning, with only a few exceptions (Södervik et al., 2022). In addition, more focused research is needed on what teachers' pay attention to in the classroom, especially in events where several simultaneous events compete for the viewer's attention. These are often unconscious actions and eye-tracking is a new method for examining such actions.

This study brings together perspectives and research traditions that have previously been more or less isolated, namely conceptual understanding and professional vision, bridging the gap between university teachers' theoretical knowledge and their action in the classroom. Our study aims to understand the role of conceptual understanding with respect to professional vision as together they form the basis of university teachers' pedagogical expertise development. The purpose of this study is to examine the relationship between (mis)conceptions and professional vision using classroom video assignment, eye-tracking, questionnaire and a stimulated retrospective recall (SRR) interview. Additionally, it investigates the development of pedagogical expertise as a result of pedagogical training, i.e., the change in university teachers' (mis)conceptions about teaching and learning and about professional vision.

1.1. University teachers' professional vision

To support student learning properly in universities requires that university teachers not only know what and how to teach, but that they are able to notice and interpret meaningfully relevant processes in teaching-learning situations to support student learning as effectively as possible (Van Es and Sherin, 2002; Sherin et al., 2011; Seidel and Stürmer, 2014). This means appropriate skills in professional vision (Goodwin, 1994). Noticing involves deciding consciously or unconsciously where to attend when observing a teaching-learning situation, and interpreting concerns the ways in which teachers draw on their knowledge to draw conclusions about what has been attended to. These two components of professional vision – noticing and interpreting – are interrelated and cyclical (Sherin and van Es, 2009). Interpreting important events also requires three interrelated processes: (1) description, (2) explanation, and (3) prediction (Seidel and Stürmer, 2014). Professional vision is especially important in teaching-learning situations where several simultaneous events compete for the teacher's attention at the same time (Shin, 2021). Thus, before a teacher can interpret the situations correctly and thus support student learning, the teacher must first learn to notice which pedagogical situations are significant.

While research on teachers' professional vision has been more prevalent in primary and secondary education, the limited attention given to professional vision in university settings is a significant gap that warrants more investigation. Studying professional vision in the university context helps us to understand how university teachers navigate these distinct challenges and make informed instructional decisions, and this understanding plays a vital role in student learning outcomes. In order to direct their visual focus of attention efficiently and consciously, university teachers need an appropriate conceptual understanding that can guide their attention in the classroom, but they also need to be able to interpret the pedagogically relevant events that they notice meaningfully by verbalizing or reflecting. Therefore, there should be a stronger focus on research on university teachers' professional vision. In addition, more research is needed to investigate how university teachers' (mis)conceptions are related to their professional vision.

The methods used to study university teachers' pedagogical expertise have been previously rather limited (Berliner, 2001; Wolff et al., 2016), mainly focusing on utilizing self-reports and interviews. In our study, the use of eye-tracking adds significant value to the research of professional vision as it measures cognitive processes in complex classroom interactions (Holmqvist et al., 2011; Beach and McConnel, 2018; Jarodzka et al., 2021; Lagner et al., 2022). However, eye-tracking methodology only enables the investigation of teachers' noticing skills, and not the interpretation of the noticed events, which is a crucial part of professional vision. Thus, eye-tracking should be combined with additional data, such as interviews, to investigate what interpreting skills lie behind the observation (van den Bogert et al., 2014). Although previous studies using eye-tracking methodology have already included qualitative interview data (e.g., Guan et al., 2006; Hyrskykari et al., 2008; Gegenfurtner and Seppänen, 2013), in the university context this type of mixed-methods approach is still rare and therefore it is needed to gain more knowledge about university teachers' professional vision development (see, however, Murtonen et al., 2022). Therefore, in this study, we use a classroom video assignment and an SRR interview to study university teachers' professional vision. Additionally, our research focuses especially on those situations where the teachers have to choose where to focus their attention while multiple things are happening at the same time in the classroom. To study this, an eye-tracking method was used.

1.2. University teachers' conceptions of teaching and learning with respect to their professional vision

Because classrooms are complex environments where multiple events happen at the same time, teachers cannot pay attention to everything that is happening. In fact, teachers' attention is very selective, and is based on their beliefs, previous experiences, and knowledge (Mason, 2002). Teachers' professional vision and their conceptions of teaching and learning are intertwined aspects of their instructional practice (Meschede et al., 2017; Sun and Zhang, 2022). By studying these aspects together, researchers can develop a holistic understanding of the complex interplay between teachers' beliefs, their observation skills, and the instructional decisions they make.

In previous teacher education research, two underlying conceptions of teaching are often distinguished, commonly characterized as either teaching as transmitting knowledge from the teacher to students or teaching as facilitating learning, that is by constructing knowledge with the students to achieve conceptual change (Pajares, 1992; Kember and Kwan, 2000; Staub and Stern, 2002; Voss et al., 2013; Kleickmann et al., 2016). Previous research has shown that university teachers' conceptions of teaching and learning vary, and less sophisticated and more sophisticated prior conceptions are found in different disciplines (Trigwell, 2002; Lueddeke, 2003; Lindblom-Ylanne et al., 2006). Teachers who conceive teaching as transmitting knowledge to students tend to employ content-focused approaches, whereas teachers who see teaching as facilitating students' learning tend to use learning-focused approaches (Parpala and Lindblom-Ylänne, 2007). Hence, less sophisticated conceptions might have an effect on teacher performance, and previous studies suggest that transmissive beliefs hinder a teacher's professional vision (Meschede et al., 2017). In contrast, university teachers' appropriate skills in professional vision seem to be related to more sophisticated conceptions of teaching and learning (Södervik et al., 2022).

In addition to the fact that university teachers' conceptions of teaching and learning vary widely, misconceptions are also apparent. For example, the presence of preferred learning styles, namely the idea that students learn best which they receive information in their preferred mode (e.g., visual, auditory, kinesthetic), is a common misconception among teachers (Dekker et al., 2012; Grospietsch and Mayer, 2018). As misconceptions related to teaching and learning are also found among university teachers (Heinonen et al., 2022), they often need to modify their existing conceptions to support the learning of their students, and this commonly requires development in conceptual understanding (Chi, 2013; Vosniadou, 2013; Vosniadou et al., 2020). In the process of such a change, pedagogical training is important (Vilppu et al., 2019; Heinonen et al., 2022; Södervik et al., 2022). However, teachers' misconceptions might often be very persistent and sometimes even hard to change (Heinonen et al., 2022). Therefore, we aim to investigate to what extent university teachers' (mis)conceptions and professional vision are affected by pedagogical training.

Based on previous research in secondary school contexts, eye-movement studies have revealed that expert teachers with more sophisticated conceptions of teaching and learning tend to look longer at students compared to novices, who focus more on teacher actions (McIntyre et al., 2017). Previous research also shows that more experienced teachers are able to focus more deeply on student learning than novice teachers, and they are able to use knowledge-based information rather than bottom-up visual observations (e.g., Levin et al., 2009). In the university context, pedagogically trained teachers seem to pay more attention to the students in the classroom than non-trained teachers (Murtonen et al., 2022). However, we still lack this type of research concerning university teachers, where eye movements reveal where university teachers are focusing in classrooms in situations where several simultaneous things compete for the teacher's attention. Additionally, little is known how teachers' (mis)conceptions affect their professional vision capabilities. Thus, our research focuses on university teachers' pedagogical expertise operationalized by both (mis)conceptions of teaching and learning and professional vision, and through the connection between them. Studying university teachers' professional vision and their conceptions of teaching and learning together is essential to gain a comprehensive understanding of their instructional practices and decision-making processes.

1.3. The aim of the study

Based on previous premises, the aim of this study is to investigate university teachers' professional vision and (mis)conceptions of teaching and learning using a classroom video assignment, a questionnaire, and an SRR interview. Furthermore, we focus in more detail on classroom incidents in which several things compete for the university teacher's visual attention, and study and test whether there are differences between teachers with less versus more sophisticated (mis)conceptions in their visual perception using eye-tracking. Additionally, we investigate how do university teachers' conceptual understanding and professional vison develop during a short pedagogical training.

2. Methods

2.1. Participants

The participants were university teachers who attended a basic university pedagogical training (5 ECTS) organized by the University of Helsinki. The university teachers who took part in the study consisted of a fairly homogeneous group. They were novices in terms of pedagogical knowledge, but they were all from the same field of research, representing eight different departments of life sciences. A total of 33 university teachers (27 female, 5 male) participated in the

TABLE 1 Study procedure.

Pre-test	Pedagogical training	Post-test
Background information ($n = 32$)	10-week university pedagogy course in Autumn 2021 (5 ECTS)	
Teacher conceptions questionnaire ($n = 32$)		Teacher conceptions questionnaire ($n = 29$)
Eye-tracking recordings + SRR interviews ($n = 31$)		Eye-tracking recordings + SRR interviews ($n = 9$)

pedagogical training held in autumn 2021. Of them, 32 participants participated in the study's pre-test; of these, 29 participated in the post-test. Unfortunately, for two participants, a stimulated retrospective recall (SRR) interview failed in the pre-test. A total of 9 participants participated in the study's eye-tracking post-test. Covid restrictions had an impact on the eye-tracking post-test.

The pedagogical training in which the data were collected was the first university pedagogy course at the University of Helsinki that provides a foundation for further pedagogical studies. To participate in the course, teaching duties at the university, or employment with the university, or study rights to pursue a doctoral degree, were a requirement.

Informed consent, and the anonymity of participants were ensured in the research process. The questionnaire and the first eye-tracking measures were part of the course assignments, but the participants could decide for themselves whether to give their consent for the answers presented in the study. Because the study involves intervening in the physical integrity of research participants (eye gaze locations), an ethical review for experiments was carried out by the University of Helsinki Ethical Review Board in the Humanities and Social and Behavioural Sciences. All experiments were performed on healthy adult test participants who gave their written informed consent.

2.2. Pedagogical training and study procedure

University teachers who participated in the study attended a short, university pedagogy course (5 ECTS) in which they familiarized themselves with basic educational theories and concepts concerning teaching and learning. This course is the first university pedagogy study at the University of Helsinki that provides a foundation for further pedagogical study. The course lasted 10 weeks and included three online meetings as well as extensive independent study. Each meeting lasted 3 h, including two 15-min breaks. The themes of the course meetings were: (1) introduction to university pedagogy, including conceptions and theories of learning, (2) factors affecting learning (e.g., metacognition, self-regulation, motivation) and prior knowledge and conceptual change, and (3) development of university teachers' expertise, and teaching and learning at the university. The contents of the course emphasized pedagogical theories and practical training, with a special emphasis on reflection as a tool to develop one's expertise development as a teacher. Meetings included traditional lecturing, but they were also used for active and collaborative learning activities, such as peer-group assignments and discussions. To complete the course, participants needed to attend all three course meetings and complete all the course requirements.

The study procedure is given in Table 1. Before beginning the pedagogical training, participants were sent the teacher conceptions online questionnaire, which included background information questions. After the first meeting, participants enrolled themselves in the eye-tracking laboratory, which was open for 3 weeks. A pre-test/post-test design was utilized, so the questionnaire was repeated in an identical form after the last meeting. Following the training, voluntary participants were invited to a post-test eye-tracking measurement. The eye-tracking post-test had to be postponed due to the COVID-19 situation in Finland. The pandemic also affected the number of participants in the post-test, and only nine participants eventually registered for the final measurement.

2.3. Measures

2.3.1. Teachers' (mis)conceptions questionnaire

All the participants filled in a questionnaire regarding their conceptions and potential misconceptions about teaching and learning. The questionnaire of 27 Likert items regarding conceptions of teaching and learning at university and seven true/false items measuring potential misconceptions, was used (Heinonen et al., 2022). The Likert items represented conceptions about (a) teaching as transmission of subject knowledge (TRAN), and in contrast, items about (b) beliefs that learning is a constructive activity (CON). All items were measured via Likert scale items, which ranged from 1 (completely disagree) to 5 (completely agree). Participants' misconceptions were examined using seven true/false items, and an opportunity to provide open-ended explanations for their answers was given (Table 2). The items concerning misconceptions were reconstructed on the basis of some previous studies (Stofflett, 1994; Grospietsch and Mayer, 2018; Vosniadou et al., 2020), to meet the purpose of this study.

2.3.2. Teachers' professional vision – classroom video annotation task and stimulated retrospective recall interviews

To study teachers' professional vision, we used a video-based task, as video-based approaches are considered to be more authentic and therefore quite a promising tool for measuring situated knowledge and teacher cognitions (Gold and Holodynski, 2015; Jarodzka et al., 2021), and to avoid problems related to self-report measures (Paulhus and Vazire, 2007; Vilppu et al., 2019). A tailor-made video represented a typical university teaching-learning situation (Heinonen et al., 2022), and it was filmed from the perspective of an outside observer (Figure 1). The video was depicting an activating university lecture, including group work and discussions. The video represents one of the

TABLE 2 True/false items measuring participants' potential misconceptions of teaching and learning.

True/false items	Scoring
(1) Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic).	False
(2) Information that is studied over longer periods is learned better than the same information studied over shorter periods.	True
(3) It always eases learning if students have preconceptions about the topic to be learned.	False
(4) Changes in students' misconceptions are mostly dependent on the teacher's ability to explain the content clearly enough.	False
(5) Deep learning means that one can repeat information adopted from the course material.	False
(6) Misconceptions are developed through students taught wrongly.	False
(7) Misconceptions are changed via proof or authority.	False

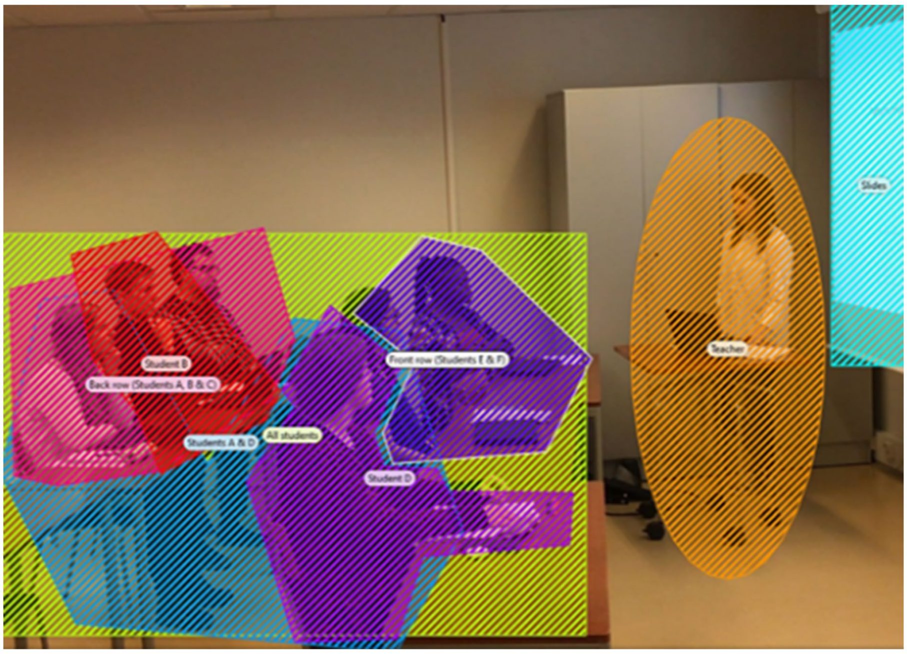

FIGURE 1
The classroom video used in the study with areas of interest (AOIs).

more typical teaching methods at the University of Helsinki. The customized video used actors as teacher and students. The video (12 min) aimed to represent as authentic a teaching-learning situation as possible, since the authenticity of video interpretations has been regarded as highly important in terms of participants' viewing experience and knowledge activation (Seidel et al., 2011). A total of 15 pre-defined pedagogically significant events, so-called incidents, were incorporated into the video. The incidents include different, pedagogically important episodes, which were designed to represent traditional learning-related theories and educational psychology phenomena, such as understanding constructivist teaching activities and being able to activate and consider students' prior knowledge in one's own teaching.

To study teachers' noticing, participants were instructed to press down the left mouse button each time they noticed something pedagogically significant and/or relevant in terms of teaching and learning. Mouse clicks were recorded in the video system and formed a time stamp. The participants' mouse clicks were not limited and they were allowed to press the mouse whenever they experienced something pedagogically significant in the video.

A stimulated retrospective recall (SRR) interview was conducted to gain a deeper understanding of the participants' interpretations of the incidents they had noticed. While rewatching the video, the researcher paused the video each time the participant had pressed down the mouse button in the first viewing. At every pause, participants were asked to recall what they were thinking during the first viewing and to think aloud what was pedagogically significant and/or relevant in terms of teaching and learning. On average, the SRR interviews lasted approximately 20–35 min. The SRR interviews (audio and visual data) were recorded using a video camera.

2.3.3. Eye-tracking In measuring teacher noticing

Five classroom incidents, where several things were occurring at the same time, were selected for the eye-tracking measurement (Table 3). In these particular incidents there was a simultaneous active role for both the teacher and the students, and the interaction of these parties played a role in these incidents. The viewer either consciously or unconsciously made a decision what to focus on (Van Es and Sherin, 2002). In the other 10 events, more homogenous observation

TABLE 3 Description of the pedagogically relevant incidents in the classroom video, where several simultaneous things competed for the teacher's visual attention.

Incident	Explanation of the incident
1	Student B (see Figure 1) raises a hand to ask a question, but the teacher ignores the student because the teacher is so concentrated on preparing lecture slides.
6	Peer group work starts, but one student (D) is left alone without a partner. However, the teacher does not notice this and does not intervene.
8	Student B raises a hand to ask a question, but the teacher ignores the student for a long time because the teacher is so concentrated on lecturing.
10	Two students (A and D) start discussing with each other while the teacher is lecturing. The teacher does not notice their discussion and other students are a bit disturbed before the teacher finally intervenes.
12	The teacher is lecturing using a very teacher-centered approach. All the students have become passive; some of them are even sleeping and some of them are focusing on their devices, such as laptops or phones. The teacher does not notice their passive behavior because the teacher is concentrating on lecturing.

behavior was expected, and the distribution of attention was presumably less due the nature of these events. In these events there was only one active party (e.g., the teacher explaining the intended learning outcomes for the lesson, or the teacher recapping the previous lesson, see Appendix). The selected five events, on the other hand, represented more complex interaction situations and required conscious or unconscious guiding of visual attention compared to the incidents mentioned above.

Participants' eye movements were recorded while watching the video to investigate where they focus their attention, in other words, what they noticed while watching the video. The use of eye-tracking has proved to be an important tool to investigate learning processes (Jarodzka et al., 2017) and a promising method for professional vision research (see, e.g., Wyss et al., 2020). Learning to make relevant observations from the classroom was one learning outcome of the pedagogical training that participants attended. Thus, a classroom video annotation task was a central part of the course content and was a mandatory task for all participants. Especially in the pre-test, the video annotation task was an important part of the course and the participants also received feedback on their own observation during the SRR interview.

A Tobii Pro Spectrum (Tobii Technology, Inc., Falls Church, VA) was used to record participants' eye movements while watching the video. Infrared cameras tracing the position of the pupils of the participants' eyes were integrated into the body of the same high-resolution 24″ computer monitor operating at 600 HZ, from which the classroom video was presented. The accuracy of the eye tracker was 0.6°. Eye-tracking data collection took place individually. The participants were briefed on the eye-tracking device and proper viewing distance and height relative to the eye-tracking device were ensured. No supporting chin rests were used, as the eye tracker allows the participants' to more their heads. When the eye tracker was adjusted, an initial five-point calibration was performed. After this, instructions regarding the video interpretation task were given. The instructions were kept very general; no hints about the upcoming incident or any other preparatory information about the video were offered. The eye movement recordings lasted approximately 15 min, including the calibration. The full experiment (eye-tracking and SRR interview) took approximately 45 min for each participant.

2.4. Data analysis

To investigate (mis)conceptions with respect to participants' professional vision, standard median splits were used to turn conception factors into dichotomous variables (that is, categorical variables with two groups). A median split was used to identify the extremes in the participants in relation to different variables. The differences between groups were tested using non-parametric Mann–Whitney U tests. Differences between participants were tested using the Wilcoxon signed-rank test. Additionally, correlations were calculated between the participants' (mis)conception and professional vision scores.

The quantitative data were analyzed using IBM SPSS Statistics 28. Principal component analyses (PCA) with Varimax rotation were conducted for the pre-test Likert-scale items concerning the participants' conceptions related to teaching and learning (KMO = 0.208, Bartlett $\chi^2[351] = 533.801$, $p < 0.001$). The PCA revealed two scale dimensions, which were exactly the same as used in the research by Heinonen et al. (2022). In the pre-test, two sum variables were used: (1) "teaching as transmission of subject knowledge (TRAN)," with an acceptable alpha ($\alpha = 0.778$) and "beliefs that learning is a constructive activity (CON)," with an acceptable alpha ($\alpha = 0.603$). In the post-test, the same sum variables were used: "teaching as transmission of subject knowledge (TRAN)," with an acceptable alpha ($\alpha = 0.653$) and "beliefs that learning is a constructive activity (CON)," with an acceptable alpha ($\alpha = 0.569$). Participants' misconceptions were scored using dichotomous scoring. Participants received a point for giving an incorrect answer to a true/false question and were given no points for answering the question correctly.

Participants' mouse clicks with their eye movements and videotaped interviews together constituted the foundation for conceptualizing university teachers' professional vision. Teacher noticing was analyzed based on timestamps from the mouse clicks, and noticing was scored using dichotomous scoring. First, the researcher counted how many pre-defined pedagogically significant events the participant had noticed during the correct time point. To be awarded one point for noticing, the mouse button should have been pressed during a pedagogically significant incident. If participants did not press the mouse button during the incident, they did not receive any points for noticing a certain incident. As the pedagogically significant incidents were based on certain time frames, it was not possible for the participant to gain noticing points by constantly clicking the mouse. Since the video included 15 pedagogically significant incidents, the participants could receive a total score of up to 15 points of noticing.

The interpreting skills of the participants were based on their videotaped SRR interviews. The SRR interview recordings were transcribed and analyzed qualitatively (Table 4). First, the transcripts were timestamped and the timing of the eye-tracking

TABLE 4 Examples of analysis units representing the domains and sub-levels of teachers' verbal interpretations.

Domains of interpreting	Points received	Example citation
Description		
Statements lacking an interpretation or providing a false interpretation or else the interpretation was not clear, for instance incorrect use of pedagogical terms and/or theories or misconceptions.	0	"Well, it wasn't related to the topic, that question, a quick answer, then an aside and then (from the teacher) the thought was interrupted, and you have to look at the screen where you were going." (P109, incident 9, pre-test)
Statements simply describing what is seen or understood to be occurring in the video, presenting only a limited and descriptive explanation of the teaching learning situation.	+1	"Well, all the students are starting to look quite upset at this point, each in their own way." (P84, incident 12, pre-test)
Explanation		
Statements representing some understanding of pedagogically significant actions by the teacher, such as facilitating or supporting students' learning.	+1	"This is clearly where students start to lose focus and motivation. So maybe now at this point we need a bit of something stimulating on the teacher's part, something about what kinds of thoughts this arouses or what do you think, because clearly now no one really listens anymore if the teacher only goes from one thing to another without involving the students anywhere in between." (P89, incident 12, pre-test)
Statements representing a clear understanding of pedagogical concepts and theories; using/linking them correctly with interpretations of the teaching-learning situation.	+1	"So now I somehow drew attention to this, that he still spends time on this, but then he says that he does not want to spend time on this. Would this be the teacher-based pedagogical method, that is, when the teacher defines what the topics are that will be discussed, and especially when, from the student's point of view, they are not necessarily terribly stimulating for the discussion or with the teaching material, because in a way, it related to this? I understand that this was a somewhat irrelevant question in a certain way, but maybe it could be handled somehow more sensibly, let us say this." (P95, incident 9, pre-test)
Prediction		
Speculation about an action that the teacher (or a student) in the video will soon take in terms of teaching and learning *or* speculation about actions that the participant her/himself would have taken in a similar situation.	+1	"So this is probably related to those students' dozing off, they do not clearly show that they are not interested, they are tired or they have already heard these things enough times or somehow too many times... They might want a break and since they have clearly shown here many times that they would like to participate and that they would like to be asked. So maybe they are somehow, maybe they are somehow not good at listening to a real lecture and they would be better in some kind of interactive activity, at least some of them... It could also be that there is somehow too much repetition in this lecture or there is somehow too monotonous rambling. You cannot know that now, and maybe it's their preliminary task... maybe they are like that because they have already become quite familiar with this matter. That's right, if the very same subject is lectured again, then the reaction may be the same, but you cannot know. Yeah." (P101, incident 12, post-test)

recordings with mouse clicks was synchronized. Next, the researcher went through the transcripts based on Heinonen et al.'s (2022) analysis framework. The aim of the SRR interviews was to gain access to the interpretation skills of the participants, while the scoring of the transcripts comprised three domains: description, explanation, and prediction, including sub-levels that were also considered Heinonen et al.'s (2022) analysis. The interview data were scored using continuous scoring ranging from zero to four points per incident.

In interpreting scores, statements simply describing what is seen in the video without any additional explanations scored one point (Table 4). If the participants' interpretation deepened from the pedagogical perspective by using explanation, the participants was rewarded from one to three points depending on the nature of the answer. Statements representing an understanding of pedagogically significant actions were rewarded one point, and statements representing a clear understanding of pedagogical concepts and theories were rewarded further point. In addition, speculation about an action that a teacher or the student would soon take was also rewarded one point. With a total of four points awarded for each pedagogically significant incident, participants could receive a total score of up to 60 points.

All excerpts from the interviews were translated from Finnish into English by the authors. The first author had the main responsibility for the analysis, but both the first author and an external, educated evaluator independently scored the SRR interview data to assess and score the quality of the participants' interpreting skills. Inter-rater reliability was determined using Cohen kappa coefficients, and there was an excellent degree of agreement between the scoring of two raters' (Cohen kappa 0.80) (Fleiss and L., 1981). After the scoring, any

TABLE 5 Participants' (mis)conception and professional vision scores in the beginning of pedagogical training.

	Max. score	*M*	Md	SD	Min	Max
TRAN ($n = 32$)	5	2.23	2.25	0.79	1	4
CON ($n = 32$)	5	4.30	4.33	0.39	3.50	5
Misconceptions ($n = 32$)	7	2.50	2.00	1.37	0	6
Noticing ($n = 31$)	15	10.55	11.00	2.20	6	14
Interpreting ($n = 30$)	60	13.30	13.00	4.60	1	23

TABLE 6 Participants' (mis)conceptions of teaching and learning with respect to their noticing of pedagogically significant incidents.

Incident no.	Results	
1	N/A	
6	N/A	
8	Teachers with fewer misconceptions focused on student B's behavior compared to teachers with more misconceptions ($Z = -2.143$, $p = 0.032$)	Teachers with more misconceptions focused on the teacher's actions compared to teachers with fewer misconceptions ($Z = -3.096$, $p = 0.002$)
10	Teachers with fewer transmissive conceptions focused on students A and D compared to teachers with more transmissive conceptions ($Z = -3.283$, $p < 0.001$)	Teachers with more transmissive conceptions focused on teacher's actions compared to teachers with fewer transmissive conceptions ($Z = -1.962$, $p = 0.050$)
12	Teachers with fewer misconceptions focused on all students' actions compared to teachers with more misconceptions ($Z = -2.223$, $p = 0.026$)	

disagreements and borderline cases were discussed during the analysis phase and resolved by expanding the coding manual and consensus discussion. In this way perfect overall reliability (Cohen kappa = 1.0) was achieved.

Incidents where selective attention was needed, were selected for a more detailed analysis. To obtain gaze data on the incidents, areas of interest (AOIs) were set in the Tobii ProLab software. A total of eight AOIs were divided, which in this study were: (1) back row (students A, B, and C), (2) student B, (3) student D, (4) student A and D, (5) front row (students E and F), (6) all students, (7) teacher, and (8) slides (Figure 1). The AOIs were defined according to who were active participants in various incidents. After defining the AOIs, the sum of visit durations (total visit duration; TVD) on each AOI was used to analyze the gaze of the participants. In order to find out the connection between the participants' (mis)conceptions and professional vision, statistical analyses were conducted. The eye movements of the groups divided by media split were compared to the divided AOIs by using the Mann–Whitney *U* test.

3. Results

3.1. University teachers' (mis)conceptions of teaching and learning with respect to their professional vision

University teachers' professional vision scores and (mis) conceptions of teaching and learning varied at the beginning of the course (Table 5). In the pre-test, the participants noticed an average of 9.78 incidents out of 15 from the video ($Md = 10.00$; $SD = 1.48$; $Min = 7$; $Max = 12$) and received on average 13.30 interpreting scores ($Md = 13.00$; $SD = 4.60$; $Min = 1$; $Max = 23$). Additionally, the participants ($n = 32$) had an average of 2.50 misconceptions related to teaching and learning ($Md = 2.00$; $SD = 1.37$; $Min = 0$; $Max = 6$).

When investigating the relationship between participants' (mis) conceptions of teaching and learning and professional vision scores in general, including all 15 incidents both in the pre-test and post-test, no significant correlation was identified.

After that, incidents that required selective attention allocation due to simultaneous classroom interactions were further investigated using eye movement data. The Mann–Whitney *U* tests revealed that with regard to three incidents, university teachers with more and less sophisticated conceptions of teaching and learning made different kinds of observations when several actions competed for the viewer's attention simultaneously (Table 6). In general, participants with more misconceptions and/or less sophisticated conceptions of teaching and learning tended to focus on the teacher's actions in the classroom video. On the other hand, participants with fewer misconceptions and with more sophisticated conceptions of teaching and learning tended to focus on the students' actions. This became evident in three out of five incidents where teachers' visual attention needed to be selectively allocated.

3.2. How do university teachers' (mis)conceptions and professional vision change as a result of pedagogical training?

The Wilcoxon signed-rank test revealed that participants changed in their (mis)conceptions about teaching and learning from less sophisticated conceptions to a more sophisticated direction (Table 7). Conceptions related to beliefs that teaching is the transmission of subject knowledge decreased among participants ($Z = -3.376$, $p = 0.009$). In contrast, beliefs that learning is a constructive activity improved among participants during the pedagogical training ($Z = -2.176$, $p < 0.001$).

The Wilcoxon signed-rank test revealed that the number of misconceptions decreased statistically significantly among participants in the post-test ($Z = -3.682$, $p < 0.001$), and that participants ($n = 29$) had an average of 1.28 misconceptions related to teaching and learning ($Md = 1.00$; $SD = 0.88$; $Min = 0$; $Max = 4$).

TABLE 7 Participants' (mis)conception and professional vision scores before and after pedagogical training.

	Max. score	Pre-test					Post-test				
		M	Md	SD	Min	Max	*M*	Md	SD	Min	Max
TRAN (pre-test: $n = 32$; post-test: $n = 29$)	5	2.23	2.25**	0.79	1	4	1.75	1.75**	0.54	1	3
CON (pre-test: $n = 32$; post-test: $n = 29$)	5	4.30	4.33***	0.39	3.50	5	4.64	4.67***	0.35	3.67	5
Misconceptions (pre-test: $n = 32$; post-test: $n = 29$)	7	2.50	2.00***	1.37	0	6	1.28	1.00***	0.88	0	4
Noticing (pre-test: $n = 31$; post-test: $n = 9$)	15	10.55	11.00*	2.20	6	14	11.67	12.00*	2.45	7	15
Interpreting (pre-test: $n = 30$; post-test: $n = 8$)	60	13.30	13.00	4.60	1	23	18.00	18.50	5.98	7	26

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

In the post-test, the participants noticed an average of 11.67 incidents out of 15 from the video ($Md = 12.00$; $SD = 2.45$; $Min = 7$; $Max = 15$) and received on average 18.00 interpreting scores ($Md = 18.50$; $SD = 5.98$; $Min = 7$; $Max = 26$). The Wilcoxon signed-rank test showed statistically significant improvement in teachers' noticing ($Z = -2.209$, $p = 0.027$), but not in their interpreting skills ($Z = -1.951$, $p = 0.051$).

4. Discussion

The aim of this study was to investigate university teachers' (mis) conceptions of teaching and learning with respect to their professional vision in general and with regard to classroom episodes, where several simultaneous things compete for the teacher's attention. Additionally, the development of university teachers' conceptual understanding was a subject of interest. This study acknowledges the importance of understanding how university teachers' (mis)conceptions influence their noticing and interpretation skills of classroom events when several things compete for the teacher's attention at the same time.

4.1. The relation between university teachers' (mis)conceptions and professional vision

The findings of the present study indicate that in general there was no significant correlation between university teachers' professional vision scores and (mis)conceptions of teaching and learning. However, with regard to classroom incidents, where the teacher was required to attend to some interactions while filtering out other simultaneous classroom activities, differences were found between teachers with more and less sophisticated conceptions of teaching and learning. Thus, the results of our study provided more insight into the assumption that teachers' conceptions and professional vision are interrelated, as suggested in earlier studies (Borko and Putnam, 1996; Blömeke et al., 2015; Meschede et al., 2017; Södervik et al., 2022). University teachers with more misconceptions and less sophisticated conceptions of teaching and learning tended to focus on the teacher's actions in the classroom video. In contrast, university teachers with fewer misconceptions and with more sophisticated conceptions tended to focus on students' actions. These outcomes are in line with previous findings (Murtonen et al., 2022), indicating that pedagogically aware teachers pay more attention to their students than teachers with no pedagogical understanding. Thus, teachers directed their attention while watching the video based on their prior knowledge of teaching and learning.

Based on theories of human cognition, individuals have only limited attentional capacity, which restricts how many events they can focus on at any given time, while irrelevant information is discarded (Kahneman, 1973; Rensink, 2009). The choice of whether to focus on the teacher or the students is reflected by the teacher's conceptions of teaching and learning (Mason, 2002). Less sophisticated conceptions are associated with content-focused approaches, which may have led to a focus on the teacher's activities. On the other hand, teachers with more sophisticated conceptions are more learning-focused, which shows their focus on the students' activities.

The results suggest that more sophisticated conceptions are a significant predictor of teachers' more developed professional vision capability in such incidents where the viewer's attention is divided between salient stimuli and irrelevant information. In contrast, less sophisticated conceptions predict noticing irrelevant actions in such incidents. Therefore, teachers' misconceptions of teaching and learning might lead to misinterpretations in real-life classroom situations, and naïve conceptions might lead to ignoring relevant incidents (Meschede et al., 2017). By contrast, more sophisticated conceptions support a teacher's ability to notice and interpret pedagogically significant incidents properly, and in that way support student learning more effectively (Södervik et al., 2022).

4.2. University teachers' (mis)conceptions and professional vision development as a result of pedagogical training

Our study showed that even a short pedagogical training can have the potential to direct university teachers' conceptions of teaching and learning from a less sophisticated to a more sophisticated direction, while pedagogical training also decreased the number of misconceptions among university teachers. Additionally, university teachers' noticing skills improved remarkably as a result of pedagogical training. After the pedagogical training, participants noticed significantly more pedagogically significant incidents in a video than before the pedagogical training. These results are in line with some previous findings related to the effect of a short pedagogical training (Vilppu et al., 2019; Heinonen et al., 2022; Södervik et al., 2022).

However, in our study the participants did not significantly improve in their interpreting skills during the pedagogical training. Since participants attended basic university pedagogical training and the participants were novices in terms of pedagogical knowledge, it is understandable that as a result of this short training, their noticing skills developed statistically significantly, but their interpreting skills did not. According to previous studies, more experienced teachers have better skills in verbalizing classroom events (Carter et al., 1988). Teachers with more experience are likely to have developed a broader repertoire of knowledge and strategies, enabling them to make more sophisticated interpretations (Stahnke et al., 2016; Wolff et al., 2016, 2017). Interpreting skills involve higher-level cognitive processes, such as making inferences, connecting information, and understanding context. These skills may presumably require practical teaching experience, which our participants were lacking, because previous studies have indicated that teaching experience is influential in the way that teachers process classroom information (van den Bogert et al., 2014; Wolff et al., 2016, 2017). More experienced teachers' interpretations are more elaborate, and they understand the connections between teacher and student activities in the classroom better than novices (Wolff et al., 2017; Stahnke and Blömeke, 2021). These processes require a deep understanding of the subject matter and the ability to integrate various sources of information. As a result, developing these skills may take more time compared to noticing skills, which often focus on more immediate and surface-level observations in general. However, in observing classroom situations where teachers attend to some interactions while filtering out others when multiple events are happening simultaneously, also involves a more complex collection of techniques that help teachers to notice pedagogical incidents (Mason, 2011). It is essential to recognize that assessing university teachers' professional vision development should consider both noticing and interpreting skills as separate dimensions. While noticing skills provide the foundation for professional vision, interpreting skills enable teachers to make sense of what they observe and make informed instructional decisions. Both aspects are vital for effective teaching and supporting the development of both skills is crucial in pedagogical expertise development.

There is an increasing interest in use of the eye-tracking measurement for instructional purposes, where teachers could receive feedback on their own observation skills (Tunga and Cagiltay, 2023). For example, eye movement modeling examples (EMME) are novel learning materials for these purposes, as modern eye-trackers can record individuals' eye-movements in a reusable format (Tunga and Cagiltay, 2023). Previous eye-tracking studies have shown that there are differences between experts and novices regarding eye-movement (Lowe, 1999; Jarodzka et al., 2010). The beauty and benefit of these EMME materials are that they enable producing of video-based learning material, where it is modeled not only, how the expert teacher interprets, but also, how they observe the classroom and students' working (van Gog et al., 2009). Utilizing of classroom videos as learning material is relatively common method in teacher education, but EMME is a novel approach and could work as teaching material to support the development of university teachers' pedagogical expertise.

Contrary to our results, some previous studies also suggest that longer periods of pedagogical training are needed for teachers to change their (mis)conceptions and point them in a more sophisticated direction (Gibbs and Coffey, 2004; Prebble et al., 2004; Postareff et al., 2007). Additionally, short pedagogical training in higher education does not always seem to be successful in changing participants' conceptions to make them more student-centered, instead the change can even point participants in a more teacher-centered direction (Ödalen et al., 2018). Thus, longer pedagogical training should be emphasized to ensure more permanent changes.

4.3. Limitations and future directions

There are some limitations to our study that need to be considered. First, due to the laborious procedure of the assessment, the sample of the study was rather small ($n = 32$), especially in the second measurement in the eye-tracking phase ($n = 9$), and therefore generalization of the findings is limited. Therefore, further research with a larger sample size is needed. In this study, the emphasis was especially on the pre-test measurement, but in the future studies it is important to have the same number of participants in both the pre-test and post-test measurement. Additionally, the study sample might have been somewhat biased, as all participants were voluntarily enrolled in the pedagogical training and therefore it can be assumed that they were motivated in terms of developing their pedagogical expertise. In future studies, it would be interesting to study professional vision and its related (mis)conceptions among university staff who have teaching duties but who do not want any further pedagogical training. Further, it would also be interesting to study university staff who have already completed more pedagogical training, and therefore might be thought to be experts in terms of pedagogical competence. Comparisons between real pedagogical experts and future faculty should be made.

Second, the participants in our study were all university teachers from the faculties of life sciences. Even though the discipline-specific perspective is one of the strengths of our research, it is still important to conduct research in the context of different disciplines in the future. To ensure disciplinary differences, it would be beneficial in further studies to compare teachers from the so-called 'soft' and 'hard' sciences. Third, in future studies it would be interesting to investigate further how teachers' professional vision is related to their actual classroom performance in real-life teaching-learning situations. In studying the development in authentic teaching-learning situations, it would be useful to use mobile eye-tracking (Pouta et al., 2020; Chaudhuri et al., 2022; Keller et al., 2022).

Fourth, the alpha value of the scale "beliefs that learning is a constructive activity (CON)," is unfortunately low and therefore the results related to this dimension and their generalizability must be treated with caution. However, the change in the scale of "teaching as transmission of subject knowledge (TRAN)," was more relevant to this study. In the following studies, it is important to perform more detailed statistical analyzes with the measure, such as confirmatory factor analysis (CFA).

Finally, short interventions provide insight into the change in teachers' (mis)conceptions in the short term. If one really wants to go deeply into teachers' conceptual changes, longer-term changes should be studied. Therefore, it would be interesting to conduct a longitudinal study in which teachers' (mis)conceptions and their possible changes would be monitored over a longer period of time. Additionally, it would be interesting to study how the changed (mis)conceptions are reflected in their real-life classroom performance.

Despite the limitations of this study, it introduced a new perspective on investigating the pedagogical expertise development of university teachers.

5. Conclusion

To conclude, in this study the general professional vision scores were not connected to the (mis)conceptions of teaching and learning, but in certain situations requiring the teacher's selective attention allocation, the observation differed between the teachers with less and more sophisticated conceptions of teaching and learning. This more detailed examination about teacher noticing utilizing eye-tracking methodology introduces a new insight into professional vision research. This study acknowledges the importance of understanding how university teachers' (mis) conceptions of teaching and learning influence their professional vision. Additionally, it showed that even a short pedagogical training can have an effect on university teachers' (mis)conceptions of teaching and learning and their professional vision.

Combining eye-tracking methodology with SRR interviews and a teacher conception questionnaire provided interesting data regarding professional vision and university teachers' expertise that would not be possible without a mixed-methods approach. Using eye-tracking methods to capture the actual cognitive processes of teachers led to new methodological leaps in investigating university teacher expertise and professional vision. Recognizing and understanding teachers' (mis)conceptions related to pedagogical theories and the need for conceptual understanding development is crucial in supporting university teachers' expertise development. This study highlights the fact that pedagogical training is needed to achieve expertise. This research also contributes by focusing on a very unique group of teachers, namely university teachers. Unlike other levels of education, university teachers are a special group, as most of them teach without any kind of pedagogical qualification or training.

Based on the research findings, we suggest that it is important to acknowledge that university teachers (mis)conceptions of teaching and learning may guide their professional vision in the classroom. In order to direct their noticing skills more consciously and efficiently and to be able to interpret the aspects that guide their noticing, university teachers require pedagogical knowledge and practical training of professional vision at the beginning of their teaching career. Thus, our study provides more insight into university teachers' pedagogical expertise development, and the results can be used to advance teacher education at a higher education level.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the University of Helsinki Ethical Review Board in the Humanities and Social and Behavioural Sciences. The patients/participants provided their written informed consent to participate in this study.

Author contributions

NH, NK, and IS: conceptualization, methodology, and writing – review and editing. NH and IS: formal analysis. NK and IS: supervision. NH: investigation, visualization, and writing – original draft. IS: funding acquisition and project administration. All authors contributed to the article and approved the submitted version.

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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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Appendix

Incidents selected for the classroom video presenting pedagogically significant events in teaching-learning situations.

Incident	Time frame	Explanation of the incident
1	0:30–0:44	Student B (see Figure 1) raises a hand to ask a question, but the teacher ignores the student because the teacher is fully concentrated on preparing lecture slides. → several things compete for the viewer's visual attention
2	0:55–1:00	The structure of the beginning lecture is presented by the teacher.
3	1:01–1:33	The teacher summarizes what has been previously learned in the course.
4	1:37–1:58	The teacher reminds the students of the pre-assignment that the teacher has given to the students at the end of the previous lecture.
5	1:59–2:07	The teacher asks students to discuss the given pre-assignment with a partner in order to activate students.
6	2:08–2:50	Peer group work starts, but one student (D) is left alone without a partner. However, the teacher does not notice this and does not intervene. → several things compete for the viewer's visual attention
7	2:53–3:40	The teacher discusses the learning outcomes for the current lecture.
8	4:15–4:45	Student B raises a hand to ask a question, but the teacher ignores the student for a long time because the teacher is so concentrated on lecturing. → several things compete for the viewer's visual attention
9	4:46–5:27	The teacher answers the student's question.
10	6:13–6:40	Two students (A and D) start discussing with each other while the teacher is lecturing. The teacher does not notice their discussion and other students are a bit disturbed before the teacher finally intervenes. → several things compete for the viewer's visual attention
11	6:41–7:42	The teacher notices that students A and D are talking and goes to ask if something is unclear.
12	7:49–8:45	The teacher is lecturing using a very teacher-centered approach. All the students have become passive; some of them are even sleeping and some of them are focusing on their devices, such as laptops or phones. The teacher does not notice their passive behavior because the teacher is concentrating on lecturing. → several things compete for the viewer's visual attention
13	8:46–9:02	The teacher asks a bad/rhetorical question to try to activate students.
14	9:45–10:13	The teacher asks a question, which activates students' prior knowledge about the topic.
15	11:07–11:16	The teacher gives all the students an activating group assignment, but the instructions are vague.

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Mobile eye tracking evoked teacher self-reflection about teaching practices and behavior towards students in higher education

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This study was based on the concept of teacher professional vision, in which professional reasoning plays a crucial role, and investigated how video with gaze overlay and heatmaps from the mobile eye tracker can support teachers' professional self-reflection and professional vision development in higher education. Four university teachers wore a mobile eye tracker in a segment of one lecture. Their gaze distribution on classroom targets was analyzed together with their reflective comments when watching the recordings of their own behavior in the lecture. The results showed that mobile eye tracking data provided feedback on the distribution of teacher attention in different areas in the classroom and between students. Visualization of gaze distribution as heatmaps allowed teachers to reflect on how they perceived their gaze allocation and most of them realized that sometimes there was a difference between how they perceived their gaze allocation and how it was captured by the eye tracker. The study revealed where teachers most often diverted their attention, which encouraged them to reflect on why this happened, to think about their professional reasoning, and to analyze opportunities for improvement. Therefore, the heatmap analysis based on the data collected with the mobile eye trackers could be used to develop the professional vision of teachers in different educational contexts for engaging students through more balanced attention to every student in the classroom. Implications for using mobile eye tracker recording and gaze distribution heatmaps in video-based professional development for teachers are discussed.

KEYWORDS

teacher professional vision, teacher self-reflection, mobile eye tracking, teacher gaze, higher education

1. Introduction

The application of technologies to facilitate professional development in teacher education is not a new phenomenon; however, with the emergence of new technologies, new possibilities appear. Learning from observing video recordings of their own teaching in the classroom has been described as a practice that advances teachers' self-reflection and the application of professional knowledge (Gaudin and Chaliès, 2015). In particular, the concept of teacher professional vision as a representation of teacher competence has been investigated in video studies (Sherin and Han, 2004). Professional vision as a concept was first formulated by Goodwin (1994), applied in different fields of expertise, and adapted for the educational field as teacher professional vision. It refers to noticing relevant events in the classroom and analyzing them according to one's pedagogical and contextual knowledge and reasoning accordingly (van Es and Sherin, 2002). Recently, the application of mobile eye tracking in authentic teaching situations has opened new perspectives for the analysis of teaching, adding the layer of following the teacher's attention distribution in the process of instruction through eye movement. Previous eye tracking studies have used mobile eye tracking to investigate teacher professional vision as it unfolds in the process of teaching and have largely focused on the differences between expert and novice teachers in noticing patterns, relevance of reasoning (Huang et al., 2021; Keller et al., 2021; Pouta et al., 2021), visual perception, attention distribution during lessons, and ability to self-reflect (Dagiene et al., 2021). Crucially, it is the idea of how the participants involved in the learning process recognize and interpret what they see (Jarodzka et al., 2021). Such studies are mainly focused on gathering visual data in authentic conditions (school classrooms) during real-life teaching, learning, and interacting. The teacher's gaze as a representation of attention is being used as a starting point for the investigation of professional vision, mainly focusing on qualitative and quantitative indicators of teacher noticing, such as target, duration, and direction of the gaze (Minarikova et al., 2021). However, less research has been conducted in the settings of higher education, where there are challenges due to the shift from a teacher-centered to a student-centered approach in teaching (Södervik et al., 2022). In the current study, the mobile eye tracking recording was used as a stimulus for teacher reflection and, thus, the activation and development of professional vision. Therefore, the research question was formulated as follows: How can mobile eye tracking technology be used to evoke a teacher's self-reflection about their classroom teaching practices in higher education?

2. Teacher professional vision in higher education and its development

In the higher education environment, teacher professional vision has been studied with pre-service teachers in relation to their preparation for future professional practice (Stürmer et al., 2017; Michalsky, 2021; Grub et al., 2022) and with university faculty as part of their teaching skills (Johannes and Seidel, 2012; Heinonen et al., 2022; Södervik et al., 2022; Murtonen et al., 2023). The latter line of studies examined university teachers' professional vision with regard to teachers' conceptions of teaching, pedagogical training, and teaching experience. Murtonen et al. (2023) explored how teaching experience and pedagogical training affected teachers' attention allocation to students versus teaching-related areas in a classroom video. The results showed that pedagogically trained teachers gazed more at the students, which led to learning-focused interpretations and assessments of classroom events and the teaching situation.

One of the challenges in higher education teaching is overcoming the transmission-of-knowledge teaching models and fostering more student-centered approaches (Lueddeke, 2003). Teaching at a university is considered different from a general school. University teachers are often seen as subject matter experts rather than educators, have more predictable classrooms compared to schoolteachers, and expect student independence, potentially overlooking student personal development (Oolbekkink-Marchand et al., 2006). Depending on their beliefs about teaching and its purpose, lecturers can vary in their inclination towards a content-oriented approach or a student-oriented approach (Postareff and Lindblom-Ylänne, 2008). The development of professional vision for university teachers becomes relevant in transitioning to more student-centered teaching, as the key aspect of professional vision is shifting the focus from oneself and one's teaching methods to the students, particularly to the changes in students' understanding of the topic taught (Sherin, 2007). Södervik et al. (2022) investigated the professional vision of current and future lecturers in relation to students' prior knowledge. Researchers found no initial differences in the professional vision of both groups regarding prior knowledge and beliefs about learning; however, future lecturers reported significantly more concerns regarding the practical applications of student-oriented teaching methods. After short pedagogical training, professional vision scores improved more for future lecturers and for representatives of natural science fields, despite the latter having more content-oriented beliefs about teaching before the intervention.

Teacher professional vision consists of two key components: noticing and interpreting events; the latter is also called knowledge-based reasoning (Seidel and Stürmer, 2014). These can be viewed as specific skills that teachers can develop (Walkoe et al., 2020). Heinonen et al. (2022) reported that short pedagogical training helped both current and future university teachers develop professional vision skills related to reasoning but not to noticing. This study reported that current lecturers initially had higher scores on professional vision compared to future lecturers. Recently, mobile eye tracking recording has been used to elicit teachers' comments about classroom management (Coskun and Cagiltay, 2021). This study showed that teachers could gradually become aware of where they allocated their attention and attempted to deliberately change the amount of attention to students. The line of research on video clubs with schoolteachers showed that when engaging in focused observations and discussions of classroom events, teachers began to pay more attention to students and noticed nuances in students' behavior and thinking (van Es and Sherin, 2010). In addition, at the university level, novice lecturers could progress from self-oriented reflections to reasoning about teaching intentions and actions during reflection-based pedagogical training. Thus, reflection-based practices can be applied to professional vision development.

2.1. Professional reflection

Teacher professional vision can be studied from an "on-action" or an "in-action" perspective (Minarikova et al., 2021). On-action research focuses on teachers' application of professional knowledge for interpreting classroom events, collecting data from teachers' self-reports, comments on classroom videos, video club interventions, and screen-based eye tracking. In-action studies directly investigate teachers' gaze behavior in the process of teaching. Teachers may also be asked to comment on their own thoughts and decisions during teaching in stimulated recall interviews (van Gog et al., 2005). Classroom videos accompanied by teachers' verbalizations have become a tool for studying teachers' professional vision and teaching practice in general (Gaudin and Chaliès, 2015).

Videos can be used as cues to help teachers remember classroom events and initiate self-analysis (Rosaen et al., 2008). Teachers who commented on videos showing their own teaching rather than videos depicting the teaching of others reported a sense of immersion in the past lesson (Seidel et al., 2011). In addition, videos of their own teaching had an activating role in the reflection process (Seidel et al., 2011). Stimulated reflection allows "stepping back" and separating reflection in action from reflection on action (Rich and Hannafin, 2009; Minarikova et al., 2021), potentially leading to the process of reframing, i.e., identifying problems in one's own practice, reasoning about them and generating solutions with predictions of how those could work in practice (Schön, 1983).

The process of reflection is often seen as both part of the teaching profession and as an instrument for professional development (Penso et al., 2001). Reports on teacher professional vision development also include teachers' reflective discussions about classroom video episodes in peer groups (van Es and Sherin, 2010). In professional and educational practice, reflection is often defined as a structured or multi-level process. Schön (1983) distinguished between a reflection in action and a reflection on action that accompany a professional activity and a reflection for action that can be considered a desirable outcome of the former two. For Van Manen (1977), reflection takes place in three stages: recognizing available skills and means for reaching a goal—technical reflection; becoming aware of the conflicts, dilemmas and complexity of the teaching situation—practical reflection; and linking wider social context to specific situations, linking them to one's own judgments—critical reflection.

Hatton and Smith (1995) referred to three levels of reflection: *descriptive*, *dialogic,* and *critical*. *Descriptive* reflection refers to individuals describing events and making attempts to provide reasons and explanations in a reporting way. The next level, *dialogic* reflection, signifies distancing oneself from the events and inquiring into the experiences with judgment, and hypothesizing and suggesting alternatives. At the highest *critical* reflection level, individuals connect the events to wider structural and socio-political contexts, considering multiple perspectives on the events. In this study, we combined teachers' initial stimulated reflection with an interview to leverage the advantages of a mobile eye tracker recording as a stimulus for reflection and to provide a possibility for a critical dialogue for teachers, drawing on the three-level reflection framework by Hatton and Smith (1995).

2.2. Affordances of mobile eye tracker recording as a stimulus for reflection

In the recent decade, eye tracking technology has evolved to the present point where portable, unobtrusive devices are available for tracking participant's eye movements in dynamic situations. Such mobile eye trackers are designed as glasses and are equipped with a front-looking camera to capture the wearer's field of view, a system of infrared light emitters, and eye cameras to capture pupil movement as well as a microphone (Tobii Pro AB, 2021a). The recording produced with the help of a mobile eye tracker shows a first-person view with a gaze overlay. Such recordings have been used as a data collection tool to study teacher professional vision in action; however, they have only recently been used directly in relation to teacher professional development (see Cortina et al., 2018; Coskun and Cagiltay, 2021; Keller et al., 2021). Using mobile eye tracker recordings for teacher self-reflection poses several advantages over other forms of classroom recordings, such as stationary cameras.

The first-person view of the mobile eye tracker recording allows teachers to review their own classroom practices from the actor's perspective rather than that of an observer, as is the case with traditional stationary videotaping of teaching. The latter may impose an unnatural perspective on teachers as observers of themselves, which may lead to self-focused emotions that hinder concentration on the teaching process (Kleinknecht and Poschinski, 2014). The mobile eye tracker recording, on the other hand, does not depict the teachers themselves and allows the focus to be maintained on the actions, students, and events in the classroom (Cortina et al., 2018).

The other unique feature of the mobile eye tracker recording, the gaze overlay, provides teachers with new, previously inaccessible objective information about their own practices. Due to the nature of the human visual system, only a limited area of the visual field can be seen at a time in high resolution; that is, the area projected on the fovea, the central sensitive part of the eye retina (Rayner, 2009). Thus, the eye has to move all the time to focus on the regions deemed the most important at the given moment. This objective information about one's focus of attention may coincide with or differ from what one consciously perceives as important (Posner, 1980), allowing teachers to receive new information about their own noticing.

Additionally, the gaze has the double function of taking in visual information and expressing meaning to others, as well as being a channel of communication for the gazer and a signal for the recipient (Argyle, 1990). Speakers can, for example, monitor and elicit responses from other people by gazing at them (Brône and Oben, 2018). The teacher's gaze is an element of non-verbal communication that serves as a social cue for learners and guides learners' attention (Fiorella et al., 2019). Non-verbal communication in the classroom, such as directing the gaze, pointing, and nodding, assists in defining turn-taking. Teachers often elicit answers from students with whom they have established eye contact (Kääntä, 2012; Gardner, 2019). Thus, teachers can become aware of the communicative role of their own gaze behavior during teaching by observing their own gaze pattern and relating it to the lecture flow. Overall, mobile eye tracker recording is an innovative video-based tool that can inform teachers about their own practices.

3. Methods

3.1. Participants and procedure

The study is based on a case study methodology. As noted by Creswell (2013), a case study allows for the exploration of a real case or cases involving different sources (Creswell, 2013, p. 97). For the analysis of university teachers' professional vision, we followed a multiple case study design (Yin, 2003). Every teacher was taken as a case when replicated eye tracking data were gathered and interviews were conducted in order to explore how eye tracking can evoke teachers' reflection and thus contribute to the development of their professional vision.

The data were collected in the autumn and winter of 2022. Four female university teachers in a teacher education department at a university in Lithuania took part in the study on a voluntary basis. Their university teaching experience varied from 4 to 25 years. The number of students in the lectures varied between 5 and 19. The researcher attended one lecture for each teacher. At the beginning of the lecture, the teacher and students were familiarized with the equipment and signed informed consent forms for participation. Then, the teacher taught a segment of the lecture wearing the glasses. Lecture topics included teaching methods (didactics), educational management, and basic statistics. Teachers were asked to deliver a segment of the lecture in the frontal teaching format to ensure that the activity type did not differ substantially between the lectures and teachers. The recording length varied between 10 and 22 min (only the first 10 min of the lecture were used for analysis). Further in this research, the participants are referred to under the pseudonyms Saulė, Karolina, Anna, and Laura.

Immediately after the first lecture, the first stimulated reflection session was conducted. The teacher was asked to watch the recording with gaze overlay and comment on her own actions and gaze behavior during teaching. The teachers could talk during the video and pause when needed. The researcher asked several questions to guide the reflection process (for example: Is there anything that surprises you about how you look?). The first session was audiotaped and lasted, on average, 15 min. The focus of the first reflective session was on the teacher's noticing focus during and after the lecture.

The second reflection session was conducted within 1–2 months after the recorded lecture and the first reflection session. This gap was due to practical reasons: the holiday period at the university and the time necessary to manually code the eye tracking recordings. In the second reflection session, the teachers were asked a set of questions aimed at eliciting critical self-reflections, identifying gaps in practice, and suggestions for pedagogical alternatives. The second reflection was stimulated by the following questions: Have you noticed anything you would like to change in the way you teach your students? What challenges could you identify that you would or may have already faced in implementing those desired changes in the second lecture? In addition, teachers were shown the heatmap from their own recording (Figure 1) as an additional cue. This session lasted around 30 min on average and was audiotaped and transcribed.

3.2. Equipment

Teachers were asked to wear a mobile eye tracking device, Tobii Pro Glasses 3, which consists of a head unit designed as regular glasses and a recording unit connected with a cable to the glasses frame. The head unit is equipped with a front-looking camera for recording a participant's field of view (resolution 1,920 × 1,080 at 25 fps), a microphone, eye tracking sensors (2 per eye), and infrared illuminators (8 per eye). The sampling rate of the eye movement recording is 100 Hz. The system is operated wirelessly from a computer with controller software (Tobii Pro AB, 2021a). Before each recording, a one-point calibration was performed (Tobii Pro AB, 2021a). After the recording, the data were transferred from the recording unit to the researcher's computer using Pro Lab software (Tobii Pro AB, 2021b), where the recording with gaze overlay was shown to the participants during the reflection session.

3.3. Data analysis

The data collected consisted of eye tracking data and teachers' reflections.

3.3.1. Eye tracking data

The eye tracking data were analyzed in the Pro Lab software (Tobii Pro AB, 2021b) using the first 10 min of each lecture (4 recordings in total). First, the heatmaps were generated for each recording through manual mapping of the teacher's fixations on the snapshot with a classroom view (Figure 1). Heatmaps were used for additional visualization of the quantitative eye movement data based on the metric *number of fixations* (Bojko, 2009). In the next step, each fixation in the recording was coded according to its target, using the codes *Student*, *Teacher material* (when the fixation targeted the teacher's computer screen and printed materials), *Board* (when the fixation targeted the board or the projected screen) and *Other* (e.g., gaze at the walls, doors, and windows). Then, a report was generated using the metrics function in the software, with indications of fixation count and mean fixation durations per target for the analyzed recording segment. Fixation-based metrics are often used in mobile eye tracking research with teachers (e.g., Cortina et al., 2015; Muhonen et al., 2020).

3.3.2. Teachers' reflections data

The audio recordings of the teacher reflection sessions were transcribed verbatim and analyzed using the thematic analysis method (Braun and Clarke, 2006, 2021) separately for each teacher, following a multiple case study approach (Yin, 2003), to examine each teacher's sense-making of her own teaching and professional vision. The teachers' reflections were analyzed and related to one of the three levels of reflection: descriptive, dialogic, and critical, according to Hatton and Smith (1995). Table 1 provides an overview of how the teachers' statements were linked to the reflection levels. Teacher reflections from the first session concentrated on their gaze behavior and reasons for gazing at different visual targets, so the results of the analysis from this session are presented under the *Noticing focus* category. The aim of the second session was to guide teachers to reflect on the areas of improvement in their practice, so part of the results from this session are presented under the *Critical focus* category for each teacher.

Quantitative indicators of the teachers' gaze behavior (number and duration of fixations on targets in the classroom) and categories from the qualitative analyses of teachers' reflections were triangulated to identify consistencies between objective and subjective data within the teachers' accounts of their professional vision (Bazeley and Kemp, 2012; Järvelä et al., 2021).

4. Results

We present the analyses of individual cases that relate to each participant's individual experiences, followed by a description of common themes across the cases. For each teacher, the results are structured under two foci: noticing and critical. Noticing focus includes quantitative indicators of the teacher's fixation distribution between classroom targets and the mean fixation durations per target, followed by themes from the teacher's first reflections on their gaze in the classroom. Here, the teacher's

FIGURE 1
Example of the heatmaps with aggregated number of fixations of the teacher in the frontal view on the classroom.

TABLE 1 Coding of reflection levels in teachers' comments.

Reflection level	Description	Examples of teachers' statements
Descriptive	Teacher reports what she observes in the recording, providing short explanations of her actions	*I am talking about the homework tasks…* *I put things in order. I watch how they choose materials…*
Dialogic	Teacher reports what she observes in the recording and provides reasons, explanations, and evaluations of the depicted events, and connects them to her previous experience	*I think it comes with experience from long time…* *I think, if some of them would go to their phones there, I would have different reactions…*
Critical	Teacher provides in-depth explanations, evaluations, and judgments of the observed events, and connects them to theoretical notions, wider social context, existing structures, and systems	*Maybe, what I could do is to ask more catching questions to involve these girls in discussion…* *I think if we did not have Covid-19 and these Teams, it would be more difficult…*

reflections on her own gaze are related to the quantitative indicators of fixation distributions. Critical focus included the themes from the session where the teachers could see the heatmap and were encouraged to critically reflect on their behavior in the lecture. The heatmaps most vividly illustrated the differences in gaze amount between individual students. Table 2 presents a summary of the themes mentioned by the teachers in the stimulated reflections.

4.1. Saulė: noticing focus

In the analyzed segment of the lecture, Saulė summarized the topics discussed in the previous lectures and introduced an upcoming assignment to the students. While doing this, Saulė looked at the teacher's computer screen and briefly at the whiteboard, where the same content was projected for the students. As seen in Table 3, Saulė gazed at the students most of the time; however, these gazes were brief compared to the other targets.

When watching the recording, Saulė described her gaze as moving quickly, thereby representing her goal of including all the students in the classroom. Saulė described the role of her gaze in the classroom as twofold: to monitor students' reactions during the lecture and to signal her presence as a teacher. She became aware that she briefly looked at each student: *I look at everyone, a little at a time, and I do not focus on anyone in particular,* and her reason for this monitoring was that it is a means of including students: *[…] if I do not look at them, then they would feel left out […] But I just do not want anyone to feel like that. So, I look at everyone, a little bit at a time.* At the same time, she reflected on how her gaze conveyed the message to the students that, as a teacher, she is paying attention to them and expects the same from them: *But I try to speak more actively, to look at everyone, and then they see that the teacher looks at everyone, sees everyone. I see everyone; I cover everyone.*

Another observation made by Saulė was that the amount of her gaze on students differed depending on where they were sitting in the classroom: *I often look at this first column, or at the second*, still trying to gaze at the back rows too: *I try not to forget them either, somewhere there.* Saulė's observation was also captured by the distribution of fixation numbers in the heatmap.

Finally, Saulė concentrated her comments on her actions in response to the information she received from monitoring student reactions. If she noticed signs of distracted behaviors, such as lack of eye contact or taking out cellphones, she would change her tone of voice and intonation, or ask questions. She also drew on her previous

TABLE 2 Overview of themes in teachers' stimulated reflections.

	First session: noticing focus		Second session: critical focus	
	Reflection level	Professional vision	Reflection level	Professional vision
Saulė	Dialogic	- Monitoring all students with the aim of inclusion - Gazing more at the first rows - Re-engaging students with gaze and prosodics - Reasoning about student (dis)engagement	Critical	- Importance of student engagement, teachers' non-verbal communication is not enough to maintain engagement in frontal lecturing - More participatory class formats are needed
Karolina	Critical	- Gazing more at engaged and well-performing students - Perceiving students as a group rather than individuals, seeking ways to engage passive students - Acknowledging gazing patterns and seeking to change them	Critical	- Need to intentionally involve disengaged students, considering the students' current emotional states and cultural backgrounds, teacher's readiness to improvise - Challenging to look for ways to introduce new topics in a non-teacher-centered manner that would be appropriate for different student groups
Anna	Dialogic	- Gazing more at familiar and engaged students - Monitoring students' reactions, being aware of the learning situation - Trying to maintain a clear structure and coherence in the lecture, building relationships with students	Critical	- Challenging to distribute attention equally between students, student disengaged behaviors distract the teacher - Interested in continuing this type of reflection in other lecture formats and durations
Laura	Dialogic	- Focusing on students and instructional materials - Gazing more at engaged students - Acknowledging lecture context and student prior knowledge	Critical	- Attention distribution reflects the lecture goals and student engagement - It is the teacher's decision to take action to (re) engage students - Interested in continuing this type of reflection in other lecture formats and durations

TABLE 3 Saulė's number of fixations and mean fixation duration on AOIs across the classroom.

	Student	Board	Teacher material	Other
Number of fixations (%)	70	1	9	20
Mean fixation duration (s)	0.26	0.22	0.39	0.19

experiences with this particular group of students to support statements about students' involvement.

Saulė's fixations on the computer screen (teacher material target) were, on average, longer than those on the students (Table 3). She did not comment on her attention on the computer screen or slides. Overall, descriptions and explanations of her own gazing behavior on the students, their engagement and ways to maintain this engagement dominated Saulė's reflections in the first session. In her comments, Saulė described her gaze and reasoned about it, also making predictions about her actions based on the actions of the students, so these reflective elements corresponded to the dialogic reflection level.

4.2. Saulė: critical focus

In the second reflection session, Saulė focused on the monitoring nature of her gaze in the lecture—briefly gazing at each student. She explained this gaze behavior from two perspectives: as a technique of public speaking to connect each listener to the content via eye contact and as a way to interact with the students, getting to know them. She found these two perspectives somewhat opposing, as even though she tried to embrace the audience through eye contact, it may not have been sufficient to engage the students on a deeper level. For that, it would be necessary to involve the students in meaningful conversations with herself as a teacher and their peers, as well as for her to understand their motivations, background, and individual learning goals. The latter means re-organizing class time and reducing teacher talk, potentially recording lectures beforehand, and mostly using classroom time for discussions and group work. She realized that maintaining a deeper level of student engagement was one of the challenges in her practice and connected it to her rather short experience as a university lecturer.

4.3. Karolina: noticing focus

Karolina started her lecture with an introduction to the new topic and briefly mentioned the eye tracking glasses. When delivering the lecture segment, Karolina used the teacher's computer to navigate the lecture slides that were also projected on a larger smart board. Karolina's lecture was a hybrid during which some students attended remotely via a conferencing tool that Karolina also operated from the computer. The major proportion of Karolina's fixations when looking across the classroom was on students and other targets (Table 4). Regarding the latter, Karolina commented that looking away from students for a moment helped her to gather her thoughts on the content of the lecture: *When I am not looking at them, I am thinking what message I want to communicate […] it is usually a little bit of concentration on the wall, or on the floor or on the table.*

TABLE 4 Karolina's number of fixations and mean fixation duration on AOIs across the classroom.

	Student	Board	Teacher material	Other
Number of fixations (%)	56	9	4	31
Mean fixation duration (s)	0.26	0.21	0.33	0.20

In addition, when watching the recording, Karolina quickly became aware that she gazed at the students a lot; however, her gaze was not equally distributed among all the students present. She noticed a pattern in her gazing: she looked more at well-performing students who demonstrated engagement: *I am looking a lot at Emma, because she is a brilliant student and she has very good comments, very good arguments … and Jane as well.* However, when reflecting on this observation, Karolina did not find it surprising, as she explained that involving active students in the lecture with gaze and questions would make her lecture more interactive, facilitating a conversation rather than a one-way content delivery. On the other hand, she admitted that while focusing on certain students, she has difficulty paying attention to the less active students and remembering their learning preferences and behaviors.

Having noted this pattern, Karolina reflected on how she could avoid it in the future by planning more strategies to elicit comments from different students in the classroom and those attended remotely in the hybrid mode, even during frontal lectures: *I should think of them more as individuals and not as a group.* Karolina noted that the recording was helpful in uncovering points for development in her teaching: *I think this is useful, because you can see that many lectures' components are working well, but some elements could be changed and slightly improved […].*

Additionally, Karolina was positively surprised that she looked at the computer screen as a prompt for the lecture less than she expected: *Actually, for me, this is, kind of, also a new thing, because I realize that I talk a lot without, how to say, having any notes. So, I think for me, it is a pleasant discovery.*

Generally, Karolina's reflective notions were contemplative in this session; she made observations and looked for explanations and alternatives to the teaching approaches she took, engaging in reflection at a critical level.

4.4. Karolina: critical focus

In her second reflection, Karolina was pleased to see from the heatmap visualization that the students were her priority. She elaborated on the importance of student engagement and a teacher's awareness of students' differences, which is also a challenge for teachers. First, she noted that it is natural for active and high-achieving students to attract a teacher's attention: *[T]he unconscious dictates that it is easier to work with students who are more intrinsically motivated, who are more involved, who are more likely to make comments, to raise questions.* The downside of this is that non-active students seem homogenous to the teacher. Underlining the need for the teacher to make intentional attempts to engage the passive students, she acknowledged the importance for the teacher to reflect, understand, and consider the fact that there will always be students who are passive in the lecture due to their emotional states and readiness to interact.

She identified the challenge of the duration of the frontal speech. In an effort to involve students more actively, it made sense to reduce the duration of frontal delivery. Presenting and explaining knowledge is important, but perhaps new methods of delivery, such as the flipped classroom approach, would allow for more active student participation, but this would require planning and adaptation to different student groups and expectations: *It may well be that what works for some groups may not work for others.*

Summarizing the reflection and the new experience of analyzing a lecture with the heatmap as a cue, Karolina noted the importance for lecturers to come to lectures prepared and with a creative attitude in order to be able to assess the situation in each group and to choose and apply the strategies that would be best suited to the students in that group: *[T]he biggest challenge is that you have to come ready to improvise. To observe the mood of the group on that day, their disposition, and your own well-being, which would allow you to organize the lecture in the most inclusive way.*

4.5. Anna: noticing focus

As with her colleagues, Anna introduced a new topic in her lecture and then presented a task to the students. Anna did not demonstrate any lecture slides and did not use a computer. In her case, the teacher material involved a set of cards that she would later distribute to the students. She also used markers to write on the whiteboard.

Most of Anna's gaze was directed at the students, and her fixations on the students were, on average, comparatively long (Table 5). When commenting on her gaze on the students, Anna noted that she tried to look at each student at the beginning of the lecture to encourage student participation: *I try to get everyone involved in the class. And it does not matter if they did the reading.* Later, she noticed that she gazed more at students with whom she was more familiar and who she perceived as more engaged: *I look at these three most of all, because they were always present in the classes.*

Anna also noted that even though it was a teacher-centered lecture, she planned a discussion exercise for students, which helped her to support their engagement and provide an opportunity to express their thoughts. After having written exercise questions on the whiteboard, Anna monitored student reactions and showed with her gaze that she expected one: *I always try not to have such awkward pauses there. I try to look at the student and tell him what he should reply to me.* Besides, it was interesting for Anna to notice that when monitoring the students, she gazed quickly not only at their faces to read facial expressions but also at their hands, how they worked with assignment cards or used their cellphones: *And here I see that my eyes are running there, to the phone, up again, I kind of keep checking them.*

When watching the mobile eye tracker recording, this teacher concentrated on the students and their participation in the activity and provided explanations for her decisions in the process at the dialogic level of reflection.

4.6. Anna: critical focus

In the second reflection session, Anna realized that she paid more attention to the familiar students who had taken part in the lectures

TABLE 5 Anna's number of fixations and mean fixation duration on AOIs across the classroom.

	Student	Board	Teacher material	Other
Number of fixations (%)	70	10	7	13
Mean fixation duration (s)	0.35	0.36	0.29	0.21

TABLE 6 Laura's number of fixations and mean fixation duration on AOIs across the classroom.

	Student	Board	Teacher material	Other
Number of fixations (%)	69	16	3	12
Mean fixation duration (s)	0.54	0.37	0.51	0.27

before. She could read their reactions as feedback on what she was saying, making sure they were following her line of thought. Anna recognized that more passive students had an effect on her lecture, as they also showed signs of unease through their body language due to the lack of contact with the course. At the same time, distracting actions of students, such as taking out their cellphones, also drew her attention and made her wonder about the reasons for the distracted behavior: *I used to worry, why are they doing this? Is it so uninteresting?*

Thus, she formulated it as a challenge to herself: how to distribute focus equally between the students and include passive and unfamiliar students in the flow of the lecture. The teacher noted that this is particularly relevant to the lectures in the hybrid format, where some of the students are in the auditorium and others attend online.

Finally, Anna noted that it would be interesting for her to continue with the recordings in larger student groups and analyze her visual behavior. If her gazing patterns were to continue, then she would need to think about other teaching strategies: *It would be interesting if I could observe more of my own lectures, so that […] I could think more about it and think about what measures I could take.*

4.7. Laura: noticing focus

In the recorded lecture segment, Laura presented a summary of the previous topics in the course in the form of a decision tree diagram depicted on a slide projected on the whiteboard. Laura moved between the teacher's computer to control the slide demonstration and the whiteboard to point to elements of the diagram during her talk. Laura gazed most at the students and the lecture slides projected on the whiteboard (Table 6). Notably, her longest mean fixation duration was on the students. Laura expressed her awareness of her gaze distribution when watching the mobile eye tracker recording: *Usually, what I am doing is looking at the [teaching] content or their faces. I am doing what I usually do, looking at the faces and eyes of students […].*

Laura's primary goal with gazing at students was monitoring their understanding and well-being: *Sometimes you are looking at someone's eyes […] it also provides some information that something is not clear, or [student] has a barrier or something;* as well as responding to students' reactions: *Because if I see someone [who] gives a signal that something is unclear, I will repeat once more. It is my duty to try to explain everything to students.* Laura also noted that knowing the background of the group and the prior knowledge of individual students helped her recognize their non-verbal reactions to the present lecture content.

Still, despite Laura's focus on the learning situation, she noted that she recognized gazing more at students who acted involved or were closer in her field of view. She noted less participation from the students in the back. However, the heatmap generated from Laura's recording demonstrated that her gaze was relatively distributed between students, with large proportions of fixations on those in the back row. She noted her awareness of less gaze on one of the students, whose expressions were hard for her to interpret. Laura's comments focused on her gaze between the students, the students' progress, and the lecture context at the dialogic level of reflection.

4.8. Laura: critical focus

In her second session, Laura acknowledged once again that she did not find her gaze distribution unusual and explained it in the context of the lecture content, her teaching goals, and her personal teaching experience in her reasoning. Still, she expected that her gaze would be more equally distributed between students, and it was somewhat surprising for her to see how the visualization represented more gaze on active students who asked questions or otherwise communicated in the lecture.

Laura presented an argument that student engagement varies depending on their background and that it is up to the teacher to decide to communicate only with those who actively show involvement or put effort into eliciting more active participation from everyone, taking into account what effect this would have on the lecture flow and reaching the teaching and learning goals. Knowing the students helps the teacher to evaluate situations and plan teaching strategies: *It is very important to allocate attention purposefully, to include slower students and to pay attention to the most active ones, but to do this correctly. You need to think carefully and plan which strategies are better suited for which audience.*

Laura expressed her interest in this type of teaching analysis and stated that it would be informative for her to take part in more mobile eye tracker recordings and observe her gaze across teaching conditions: in lectures of different formats, such as group discussions, with a varying number of students and for a longer period of time. She showed openness to more observations and reflection with the goal of professional development.

4.9. Recurring themes

The descriptive quantitative results from the mobile eye tracker recording (Tables 3–6) demonstrate that all four teachers prioritized students with their gaze, with 56 to 70% of fixations in the recorded lecture segment being on students. All the teachers also had longer mean fixation durations for student and teacher material targets and shorter fixation durations for less relevant objects in the classroom.

The teachers' descriptions of their visual gaze behavior, as seen from the mobile eye tracking video recordings, seemed to support the fixation-related indicators considered in the present study. Furthermore, each of the four case study teachers mentioned giving visual attention to either the majority of the students present in the classroom or to some students in particular. The students'

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demonstration of active participation in the lecture and position in the classroom influenced how they attracted the teacher's gaze. Only Laura explicitly reported that the way she looked across the classroom was how she would expect herself to act, while the other three teachers came to new realizations about their gaze distributions. In line with this, Laura was also the least prone to suggest alternatives for teaching based on the recorded lecture segment. Thus, the dominating lens of how teachers reflected on their own professional vision was the teacher's interaction with the students through being present as a teacher—paying attention to students and sustaining their attention on the lecture content.

Another recurring point when encouraged to reflect on their gaze behavior, and its distribution across classrooms illustrated by the heatmap images, was teachers' focus on lecture organization, student participation, and classroom layout. We deliberately sought frontal teaching segments of the lecture for the present analysis; however, all the participating teachers pointed out that this format was not always beneficial for sustaining students' attention on the content and, in their critical reflections, suggested reducing the frontal teaching elements for conveying theoretical materials through, for example, flipped classroom methods (e.g., Giannakos et al., 2015).

At the same time, the levels and depth of reflection with the mobile eye tracker recording as a stimulus varied from teacher to teacher. All teachers provided explanations for their gaze behavior and actions in the lecture in the first reflection session; however, only Karolina made observations about her gazing pattern and stated the need to look for alternatives for teaching decisions. In the second session, which sought to elicit teachers' critical reflections, the teachers looked for reasons and explanations for their gaze distribution. All teachers were able to recognize the need to consider the role of gaze distribution in their teaching—the inclusion of students in the learning process. They also reflected on possible ways to ensure a more balanced gaze distribution by taking into account students' backgrounds, prior knowledge, and current emotional states, and planning for these before the lecture and adapting during the lecture, as well as reconsidering the format of frontal teaching based on its effect on student participation.

5. Discussion

This study aimed to explore the ways of employing mobile eye tracker recording as a tool for the professional self-reflection of teachers with a focus on professional vision in higher education settings. To this end, quantitative indicators of the teacher's gaze across the classroom during the lecture and the teacher's reflective comments on the recording and gaze visualizations were combined in a case study. The analyses of the four cases demonstrated that university teachers prioritized students in the lectures both with their gaze and in reflective comments and showed awareness of their gaze behavior to different extents. In addition, the teachers' reflective comments on the video were at different reflection levels.

The teachers in our study concentrated their gaze and reflection mostly on the students, noting students' engagement and opportunities to participate in the lectures. This is in line with previous findings that teachers, especially experienced ones, allocate their attention to students rather than other targets in the classroom (McIntyre et al., 2019; Huang et al., 2021) and tend to distribute their attention evenly between students, demonstrating monitoring behaviors (Cortina et al., 2015). As previous mobile eye tracking studies were conducted at the secondary school level, our study expands the existing research by focusing on the noticing and reasoning of higher education teachers. The present study shows that student engagement and participation are of concern to university teachers, even though they are usually regarded in the literature as less student-oriented than schoolteachers (Oolbekkink-Marchand et al., 2006). At the same time, this could be because the participants in the present study were all teacher educators, as previous research with participants across different departments at universities noted that lecturers in the social sciences tended to have student-oriented rather than content-oriented beliefs compared to lecturers from the natural sciences (Lueddeke, 2003; Södervik et al., 2022). Additionally, examining the heatmap of their gaze allocation in the classroom provided teachers with an opportunity to reason about looking at certain students, revealing teachers' inclination to either look more often at disengaged students and those sitting further away or to look at the more engaged and visually accessible students. Recent research demonstrated that teachers were able to notice subtle variations in student behavioral cues and linked them to student learning profiles, and experienced teachers judged inconsistent student profiles more accurately than novices (Seidel et al., 2021). In higher education, students, as adults, can exert more control over visible behaviors and demonstrate learning through written assignments rather than performance in lectures. Further research is needed to investigate how university teacher characteristics, such as experience, awareness of own teaching approaches, and teaching beliefs, relate to teachers' sensitivity and gazing patterns to observable student engagement in the lectures.

The objective part of the data—the gaze cursor in the mobile eye tracker recording and its aggregated visualization on the heatmap images—was a source of insight for the participants in the present research. Similar to the study by Coskun and Cagiltay (2021), university teachers could recognize the amount of gaze on students in the classroom and reflect on its meaning for student engagement and classroom management. By eliciting teachers' reflections about their own gaze behavior and gaze distribution, this study further developed the possibility of using teacher gaze as objective feedback in teaching situations (Cortina et al., 2018; Keller et al., 2021). Teachers also considered their gaze as an intentional non-verbal communication channel during teaching. Research has shown that teachers' non-verbal immediacy helps sustain the attention of the students during lessons and has an indirect effect on their performance (Bolkan et al., 2017). More research is needed to understand how informative it is for teachers to see their own gaze behavior and how this experience influences their teaching in the future.

The teachers' reasoning about their own actions in the classroom happened at the *dialogic* and *critical* reflection levels. This indicates teachers' responsiveness to using mobile eye trackers as reflection stimuli and as an impetus to explain interactions with students in the classroom and develop their professional vision. Supporting the quality of teacher reflection is essential in using video in professional development activities (Geiger et al., 2016). Some teachers may be more open than others to critically examining their practices. In this study, only one teacher reflected critically in the first session, and the other teachers provided critical comments in the second session that aimed to encourage such reflections, so a guided reflection session may be one of the ways to help teachers consider alternatives for their current teaching approaches. As stimulated reflections have become an increasingly common tool in the professional development of pre-service teachers (Rich and Hannafin, 2009) and in-service teachers in school education (van Es and Sherin, 2010), this study demonstrates the possibility of using classroom recordings to support university teacher professional development.

5.1. Implications and limitations

This study has implications for using mobile eye tracking recordings in teacher professional development activities. As a continuation of video-based learning activities, the mobile eye tracker recording offers objective feedback for teachers about their attention focus and use of gaze for non-verbal signaling to students in the classroom. In addition to previous usage of mobile eye trackers for teacher reflection (Coskun and Cagiltay, 2021; Keller et al., 2021), several recommendations that draw on the current study results can be made for teachers to benefit from the unique features of the technology:

1. Allowing teachers to watch the lecture recording several times can let them get used to the nature of the recording and can facilitate noticing and identification of gazing patterns.
2. Having a researcher guide the stimulated reflection with questions supports critical reflection. This approach can assist teachers in recognizing patterns in their teaching and gaze behavior, thereby challenging their existing views on classroom performance.
3. Generating artifacts, such as heatmaps or scanpath images, illustrates the aggregated gaze distribution, and provides a summary of the gazing behavior and a stimulus for the teacher's reasoning.
4. Following up with the teachers about any perceived effects of stimulated reflection on their teaching.

At the same time, from the perspective of eye movement research, some caution in the interpretation of eye movements in the teaching context is needed. Although there is evidence that gaze behavior and teaching expertise are associated (van den Bogert et al., 2014; Cortina et al., 2015), eye movement is a physiological process and does not directly represent the quality of teaching of each individual teacher. Teachers need to be informed about the nature of eye movement and how it can be interpreted when they watch the mobile eye tracker recording to avoid forming misconceptions about their own visual behavior. Moreover, even when teachers notice some gazing patterns, they may not know how to assess these patterns and whether they need to be interpreted critically. For example, the teachers in the present study noted that it was logical for them to pay more attention to those students who communicated during the lecture, verbally or non-verbally, through sustained eye contact. Teachers can be guided to formulate insights from such observations for further practice.

Another important point is selecting teachers for participation who could benefit from stimulated reflection. Expert teachers may already exhibit gazing patterns that signify a focus on the learning process, while novice teachers may be open to finding critical points in their teaching and be responsive to feedback and improvement.

Some practical issues related to collecting eye tracking and video data must be considered. As mentioned previously, videotaping can generally be considered a sensitive situation for teachers. Eye tracking is a new experience for most individuals, and it reveals private information about where one is looking in the real-world environment. In addition, the students in the classroom may influence the teacher's overall and gaze behavior, depending on the size of the group, how students are seated, and the previous experience of the teacher with the group. These need to be considered in organizing video-based professional activities for teachers. It may be beneficial to start with simulated lectures, such as micro-teaching situations, to familiarize teachers with the procedure and value of eye tracking, especially for novice teachers. This can also help minimize the ethical issues of collecting, processing, and storing the personal data of teachers and students.

Other practicalities of including eye tracking in professional development relate to the specifics of the technology. As in all eye tracking research, there are requirements for the participants. For example, they cannot wear normal sight-correcting glasses together with eye tracking ones; thus, teachers with weaker eyesight would be asked to wear contact lenses for the recorded lectures. The eye movements of individuals with certain eye conditions cannot be tracked, and the accuracy of eye tracking decreases with senior-age participants (Holmqvist et al., 2011; Tobii Pro AB, 2022). In addition, while the cost of mobile eye trackers decreases and more providers and equipment options become available on the market, the data collection and processing still require time and human resources, which need to be accounted for in the cost of this professional development activity.

This study has several limitations. It was a case study with a limited convenience sample that included only female teachers in one university department; therefore, the results cannot be generalized. Further studies may aim for a more diversified sample. In addition, the lectures and recordings took place in rooms with different layouts, which affects how visual targets appear in teachers' fields of view and, consequently, how teachers distribute their gaze. Additionally, it would be advantageous to consider other approaches to data analyses, such as scanpath analysis, which considers the gaze from the temporal perspective (Kaakinen, 2021). Recording several lecture episodes for each teacher in various teaching situations, as in the study by Smidekova et al. (2020), would also provide teachers with a more comprehensive overview of their own gazing patterns.

Data availability statement

The datasets presented in this article are not readily available only parts of the dataset in anonymized form can be presented upon request to the corresponding author. Sharing of the data would need to be approved by the authors' institution. Requests to access the datasets should be directed to kateryna.horlenko@vdu.lt.

Ethics statement

The studies involving human participants were reviewed and approved. The research was carried out following the provisions which underline the basic principles of professionalism and ethics of research, approved by the Resolution No. SEN-N-17 of the Senate of

Vytautas Magnus University of 24 March 2021. The study was conducted in accordance with the principles of reliability, integrity, respect, and accountability and with the provisions of point 23, which define the cases in which the investigator is required to submit to the evaluation committee his/her research plan for the validation of compliance with the professionalism and ethics of the research. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

LK, KH, JM, TP, AR, and IT-B made substantial contributions to the study design, analyzing, and interpreting the data. LK led the study and provided feedback to substantially improve the manuscript. KH and JM collected, analyzed the data, and produced the first draft of the manuscript together with TP. TP, AR, and IT-B contributed to the conceptual development and writing of the manuscript. All authors contributed to the article and approved the submitted version.

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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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Assessment of noticing of classroom disruptions: a multi-methods approach

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Teachers' noticing as a basic precondition for effective teaching is characterized by focusing on relevant events in the classroom and ignoring the irrelevant. In recent years, many researchers have used eye-tracking methodology in classroom observations to gather information about the continuous attentional processes of teachers. Despite the general validity of the eye–mind assumption, methodological triangulation is necessary to draw conclusions about the where and why of the focus of attention. Although in previous studies, different data sources like gaze and verbal data have been used, the analyses were mostly conducted separately, instead of directly combining the data. In our study, we collected verbal data (retrospective think-aloud; RTA) and a reaction-based concurrent measure (keystroke) to assess the noticing process of novice and experienced teachers ($N = 52$) while they watched staged videos of classroom situations. For a direct triangulation, we combined these data with eye-tracking data. The aim of the study was to combine both measures with eye-tracking parameters that indicate attentional processes (fixation count, mean fixation duration, and revisits), and with expertise. We found that participants who were aware of the critical incidents in the videos (they gave a keystroke or mentioned the incident in the RTA), showed—as expected—a higher number of fixations and more revisits to the appropriate area, but a comparable mean fixation duration. However, expertise differences regarding accuracy in both measures could not be shown. We discuss methodological issues regarding the implementation of RTA and keystroke as measurements for the noticing process because—despite only partially significant results—both methods are promising as they allow complementation and possible correction of eye-movement-only data.

KEYWORDS

noticing, classroom management, triangulation, eye-tracking, stimulated retrospective think-aloud, keystroke

1. Introduction

Teaching as an interactive and complex profession needs spontaneous and flexible decisions to handle the requirements of individual situations (Doyle, 1985). In the classroom, features that need attention are, for example, potential disturbances (Grub et al., 2020), student hand-raising (Kosel et al., 2023a), or uninterested or struggling students (Seidel et al., 2021). Only when teachers are able to place a conscious focus on the mentioned aspects, they can react adequately (e.g., Grub et al., in press). Teachers' noticing—also often named as professional vision (PV)—as an important prerequisite for their professional behavior can be understood as a situation-specific skill to perceive and interpret the demands of the situation (e.g., Blömeke et al., 2015). In particular, the basic perceptual process of attending to relevant elements in the classroom and ignoring the irrelevant is a widely investigated construct in research on teacher professionalization (König et al., 2022), although there are different conceptualizations and definitions of the terms (Stahnke et al., 2016; König et al., 2022). Despite the various definitions, it has been shown that expert teachers with an elaborated knowledge structure are better able to attend to the specific relevant features of a situation than novices (Lachner et al., 2016; Stahnke et al., 2016; Wolff et al., 2016, 2021; Boshuizen et al., 2020; Grub et al., 2022a). Due to technical development in recent years, a direct assessment of the noticing process is possible with process-based measurements such as eye-tracking and they are increasingly used in research of teachers' noticing (Grub et al., 2020, in press; Stahnke and Blömeke, 2021a).

A basis for eye-tracking research is the eye–mind assumption, which means that conclusions about cognitive processes can be drawn from fixations in a given moment (Just and Carpenter, 1980). This hypothesis is debatable, because it overlooks hidden attention or parafoveal perception, and it is unclear from eye-tracking data alone why a person fixates on a given stimulus (Posner, 1980; Anderson et al., 2004; Holmqvist et al., 2011; Jarodzka et al., 2017; Orquin and Holmqvist, 2018; Schindler and Lilienthal, 2019). This leads to the necessity of triangulation using additional measurement methods (Orquin and Holmqvist, 2018; Gegenfurtner et al., 2023; Grub et al., in press). For this purpose, in research on teachers' noticing, verbalization methods such as think-aloud protocols are often used (Wolff et al., 2016; Stahnke and Blömeke, 2021b; Grub et al., 2022a). However, in most cases, the different data sources are not cross-linked but rather are analyzed separately from each other. A direct link between eye-tracking measurements and verbal data for assessing attentional processes has been implemented only in a few studies (Yamamoto and Imai-Matsumura, 2013; Wyss et al., 2020).

A look toward other research fields, where focused attention and quick reaction are based on the perception of visual stimuli in dynamic scenarios, is worth considering to identify further methods that assess attentional processes. For example, in traffic psychology, a widespread method is the keystroke task to assess attentional processes in hazard perception scenarios (e.g., Malone and Brünken, 2020). Such reaction-based tasks are already used in research on teachers' noticing, but the generated timestamps are used to select material for the analyses (e.g., van den Bogert et al., 2014) or as cues for retrospective think-aloud protocols (RTA; Stahnke and Blömeke, 2021b), and not for analyzing attentional processes itself.

In the present study, we aimed to investigate where the participants had their particular attention during the observation process. For this, we use reaction-based measurement (keystroke) and stimulated RTA to measure the noticing process and validated the data with different parameters of gaze behavior as well as with expertise. More precisely, we aimed to investigate, on one hand, whether the participants who noticed critical incidents (CIs) in the scenarios differed in their attentional gaze behavior (fixation count, fixation duration, and revisits). On the other hand, we aimed to determine whether experts showed higher accuracy in noticing CIs with keystroke measurement and RTA when compared to novices.

1.1. Teachers' noticing

It is indisputable that the perception of essential cues within a profession is a key component of expertise, especially for teachers (Blömeke et al., 2015; Stahnke et al., 2016). Nevertheless, different authors use different conceptualizations and names for the construct of the perceptual processes (Stahnke et al., 2016; König et al., 2022). The concept of Professional Vision was originally introduced as a holistic concept from a sociocultural perspective by Goodwin (1994). It describes a specialized way of seeing and understanding meaningful events in a specific professional context. The adaptation of the concept in the context of teaching entailed a shift to a cognitive psychological perspective and was first used by Sherin (2001) (see also Sherin and van Es, 2009; Seidel and Stürmer, 2014) with the intertwined subprocesses of selective attention (noticing) and knowledge-based reasoning (Weyers et al., 2023b). In later publications, Sherin and van Es subsumed the perception and reasoning process under the term noticing (van Es and Sherin, 2002; Sherin et al., 2011). Other authors added the decision-making process (Jacobs et al., 2010; Kaiser et al., 2015) or rather the concept of shaping (van Es and Sherin, 2021) to noticing; while some concepts only subsumed the perceptual process under this term (Star and Strickland, 2008; Seidel et al., 2021). The common feature of these analytic approaches (König et al., 2022) is the possibility of separate consideration of the subprocesses. An empirical example is the study from Seidel and Stürmer (2014), who referred on the term professional vision and the subprocesses of reasoning. The authors could show in their study that a three-factor model with the components description, interpretation, and prediction fits better than a one-factor model (see also the study of Weyers et al., 2023a). We follow the analytical approach and focus with the term noticing only on the attentional focus of teachers (see the narrower definition of Star and Strickland, 2008 and Seidel et al., 2021).

In all previously mentioned conceptualizations, expertise, and the accompanying professional knowledge, is a crucial basis for noticing (Blömeke et al., 2015; Stahnke et al., 2016; Grub et al., 2020, 2022a; Wolff et al., 2021). Even the perceptual focus on relevant cues presupposes knowledge of the relevance (or irrelevance) of signals for teaching and learning. The direction of attentional processes can be based on professional knowledge (top-down), but also on salient cues in the situation itself (bottom-up; see; for example; Wolff et al., 2021; Gegenfurtner et al., 2023). From expertise research, it is well known that experts with a professional knowledge base, that has well-structured and organized schemata, are better able to direct their attention to relevant cues than novices (Lachner et al., 2016; Stahnke et al., 2016; Wolff et al., 2016, 2021; Boshuizen et al., 2020; Grub et al., 2022a).

1.2. Measuring the noticing process

1.2.1. Eye-tracking

In the last nearly 15 years, however, process-based methodologies such as eye-tracking have been increasingly used in research on professional vision of teachers, and thus, have been able to provide further insight into the noticing process (Grub et al., 2020, in press). For example, eye-movement data reflect attention and shifts in attention (van Gog et al., 2009) and can be used to assess and analyze teachers' allocation of attention in the classroom (Bucher and Schumacher, 2012; Beach and McConnel, 2018; Haataja et al., 2019; Grub et al., in press). According to the eye–mind assumption (Just and Carpenter, 1980), the cognitive processing of an object corresponds to the visual focus or rather the fixation on the object. A fixation is defined as "a period of time when the eye is relatively still" (oculomotor definition; Holmqvist et al., 2011, p. 377). Therefore, gaze-based indicators for attention, number of fixations, and fixation duration can be used (Holmqvist et al., 2011). Furthermore, analyzing revisits (areas of interests—AOIs—where people look back) allows conclusions to be made about the relevance of AOIs for participants (Wolff et al., 2016; Grub et al., 2020). Many studies in the context of professional vision in teaching lay their primary focus on contrasting novice and expert teachers (Wolff et al., 2017; Seidel et al., 2021; Shinoda et al., 2021; Stahnke and Blömeke, 2021a,b; Grub et al., 2022b), but not on the attentional focus itself. From these studies, it is known that expert teachers place a stronger focus on relevant aspects of the classroom (e.g., disruptions or hand raising-behavior). Yamamoto and Imai-Matsumura (2013) and Wyss et al. (2020) both directly focused on attentional processes, showing that participants who were aware of a CI fixated on it more often and with a longer duration (see Section 1.2.2 for further description of the studies).

Nevertheless, inferences about the cognitive processes or location of an individual's attention made from eye-tracking measures alone can be imprecise and skewed because of parafoveal processes (Anderson et al., 2004) as well as hidden attention (Posner, 1980). Therefore, it is strongly recommended that gaze data should be complemented with other measurements to identify where attention is actually being directed (methodological triangulation; Denzin, 1989; Holmqvist et al., 2011; Orquin and Holmqvist, 2018; Grub et al., in press).

1.2.2. Post hoc verbalization and standardized tests

For assessment of the noticing process—that is, of *what* was seen—standardized instruments (for an overview see Weyers et al., 2023b), as well as RTA protocols (Wolff et al., 2015; Stahnke and Blömeke, 2021b; Grub et al., 2022a), are worth considering. Standardized test instruments are used in most cases after the actual stimulus materials, in the form of videos or pictures of teaching scenarios in combination with open- or closed-ended questions. Most of these tests differentiate between the dimensions of professional vision or noticing (attending/perception, reasoning, and decision-making; Weyers et al., 2023b), but do not represent the spontaneity of classroom situations (Stahnke and Blömeke, 2021a).

Likewise, the think-aloud method (Ericsson, 2018) in the context of professional vision uses videos or pictures as stimulus materials (Wolff et al., 2015; Stahnke and Blömeke, 2021b). The verbalizations of participants will give insight into their cognitive processes as they handle a task (e.g., the observation of a teaching situation). Although the concurrent collection of verbal data during the task is a more accurate and valid procedure (Ericsson, 2018), it is not suitable for complex tasks such as teaching, or for use while eye-tracking, because the think-aloud process can distort gaze behavior and the cognitive processes themself (van Gog et al., 2005; Prokop et al., 2020). Therefore, the collection of verbal data takes place after the observation of a scenario and is often supported with videos (with or without integrated eye-movements), which are used as cues to increase the validity of the verbal data and avoid oblivion or fabrication problems (van Gog et al., 2005; Prokop et al., 2020). With these stimulated RTA protocols, researchers have investigated attentional processes in teaching (with instructions such as "Could you tell me, what you have seen?"; Wyss et al., 2020; Grub et al., 2022a), as well as reasoning processes, whereby participants are prompted to report their thoughts about what they have seen and the importance of the stimuli (Wolff et al., 2015, 2016, 2017; Gegenfurtner et al., 2020a; McIntyre et al., 2021; Grub et al., 2022a).

Combining verbal methods with eye-tracking as measurement methods of the noticing process is a promising approach (Wolff et al., 2016; Beach and McConnel, 2018), and previous studies of teachers' professional vision have used multiple data sources such as eye-tracking and (stimulated) RTA protocols (Wolff et al., 2016; Pouta et al., 2020; Stahnke and Blömeke, 2021b; Grub et al., 2022b). Nevertheless, in these studies, the data sources were analyzed separately from each other rather than being directly combined. In contrast, a direct combination of eye-tracking data and RTA was used by Muhonen et al. (2021, 2023) to investigate reasoning processes, as well as by Wyss et al. (2020) and Yamamoto and Imai-Matsumura (2013) to investigate attentional processes. Wyss et al. (2020) combined eye-tracking data and RTA for one short video clip to examine the association between the awareness of a CI and the gaze behavior of the participants (student teachers as novices and university teacher educators as experts). From the RTA protocols, they identified who mentioned the CIs and who did not and analyzed the gaze behavior of the two groups. First, they showed that expertise was connected to the identification of the CI (only experts were aware of them), and second, they showed that participants who were aware of the CI evidenced more and longer fixations on the incident. Nevertheless, the study had some drawbacks regarding generalizability: only six of the 56 participants were aware of the CI, and the authors used only one short video clip with one incident. Also using a comparable design with one short video, Yamamoto and Imai-Matsumura (2013) also found differences regarding fixation count (aware participants had more fixations) and fixation duration (a longer duration for aware participants). Since the cultural context of this latter study was situated in Japan, in East Asia, the transferability of the results to the Western context is potentially problematic.

1.2.3. Concurrent measures

In the field of traffic psychology, reaction-based measurement during the observation of traffic scenarios is a common method for investigating the skill of hazard perception (the ability to detect and evaluate road hazards quickly; Horswill and McKenna, 2004; Malone and Brünken, 2020). As the task is for the observers to press a key when they identify a relevant cue within the scenario, an inference to the corresponding cognitive attention process is possible (Chapman et al., 2002). This reaction-based method is a valid measurement in hazard perception research (Malone and Brünken, 2016; Moran et al., 2019): Experienced drivers react faster to CIs, and they identify more potential hazards correctly; this also applies to drivers with less accident liability (Malone and Brünken, 2020). Keystroke tasks have also been applied in research into the PV of teachers, but they are used as stimulus segments for RTA (e.g., Stahnke and Blömeke, 2021b) or for analyzing a selection of video segments in depth (van den Bogert et al., 2014), rather than for analyzing the focus of the teachers' attention. Like eye-tracking, the attentional process can directly be covered with a keystroke during the task but it should be combined with the fixations from eye-tracking to identify the location of the visual attention (Crundall, 2016; Malone and Brünken, 2020).

1.3. Aims and hypotheses

In the present study, first, we aimed to investigate whether keystroke measurements and the RTA are appropriate ways of assessing the noticing process (awareness of a CI). The first step is methodological triangulation with the eye-tracking parameters fixation count, fixation duration, and revisits, which corresponds to the focus of attention and the relevance of the area of interest (AOI) for the participants. Second, we aimed to validate the measures using the expertise of our participants.

For the first research question, we wanted to identify whether participants who were aware of a relevant CI in the videos (assessed with keystroke as well as with RTA) showed differences in their gaze behavior. According to the eye–mind hypothesis, the focus of attention can be inferred from the location of fixations (Just and Carpenter, 1980; Holmqvist et al., 2011). Wyss et al. (2020) and Yamamoto and Imai-Matsumura (2013) both showed that participants who were aware of a CI had more fixations on the CI and a longer fixation duration. Wolff et al. (2016) indicated that participants had more revisits to AOIs of higher relevance, which referred to a conscious noticing of the AOI.

> *Hypothesis 1a:* Participants who identify the CI correctly with a keystroke (they press a key and have a fixation on the CI within the relevant time period) will have more fixations, a longer fixation duration, and more revisits.
> *Hypothesis 1b:* Participants who mention the CI in the stimulated RTA protocols will have more fixations, a longer fixation duration, and more revisits.

For the second research question, we wanted to examine whether expert teachers (experts) were more aware of the CI than prospective teachers (novices). Experts in the field of teaching are better able to direct their attention to relevant cues; that is, they have more fixations on these AOIs than novices (Lachner et al., 2016; Stahnke et al., 2016; Wolff et al., 2016, 2021; Boshuizen et al., 2020).

> *Hypothesis 2a.* Experts will identify more CIs correctly with a keystroke (they press a key and have a fixation on the CI within the relevant time stamp) as novices.
> *Hypothesis 2b.* Experts will identify more CIs in the stimulated RTA protocols than novices.

2. Materials and methods

2.1. Participants

A total of $N = 71$ student and experienced teachers participated in the study. Teachers ($n = 37$) were recruited via email, telephone, and newspaper from schools in South-Western Germany and had at least 5 years of teaching experience. Student teachers ($n = 34$) were recruited via email lists and flyers at Saarland University and had a maximum of 40 h of teaching experience during their regular practice. Data from 12 participants (six experts, six novices) were excluded from the analyses due to insufficient data quality (e.g., an outlier with more than three standard deviations for at least one of the relevant variables). In addition, only those participants for whom both gaze and verbal data were available were used in the analyses. Thus, 26 student teachers and 26 experienced teachers remained ($N = 52$); see Table 1 for the details of the sample.

2.2. Design and procedure

We re-analyzed data from an already published study (Grub et al., 2022b) for the purposes of the present study in support of the intensive use of scientifically generated empirical data (Machado, 2015; see Müller and Gold, 2023; Kosel et al., 2023a, for examples). Overall, the participants observed seven short videos of staged lessons in mathematics and informatics. For the re-analysis presented here, we focused on only two of the videos with, in total, five CIs regarding classroom management (see Section 2.3 for more details).

The study consisted of three sequential parts (see Figure 1). In *Part 1*, participants answered a knowledge test and demographic questions, which were presented online on Unipark. *Part 2* of the experiment, an eye-tracking experiment in the laboratory, took place 10 days later, on average. Here, participants were quasi-randomly assigned to one of six video sequences, in which the videos were balanced regarding the order of presentation by Latin square to exclude sequence effects (the first of the seven videos was always the same and was provided as a tutorial video). The participants' eye movements were recorded as they observed the videos. Meanwhile, the task was to identify CIs in each video via a keystroke. In *Part 3*, a stimulated RTA based on individual eye-tracking data was performed directly after watching all the videos, in which the eye movements presented as scan paths served as a cue for verbalization. During this stage, the noticing process was assessed by asking participants to explicitly specify the previously identified events in more detail. In total, the experiment lasted around two hours (*Part 1*: around 45 min, *Part 2*: around 20 min, *Part 3*: around 55 min).

2.3. Apparatus and videos

Eye movements were recorded under standardized environmental conditions using a stationary, binocular eye tracker (Tobii Pro

TABLE 1 Demographic information.

	Novices ($n = 26$)	Experts ($n = 26$)
Age (in years)[a]	23.81 (6.02)	43.15 (9.54)
Gender	♀ 88.5%	♀ 46.2%
Teaching experience[a]	5.00 (9.60) hours	13.85 (7.94) years
Semester[a]	2.35 (2.64)	/

[a]*M(SD).*

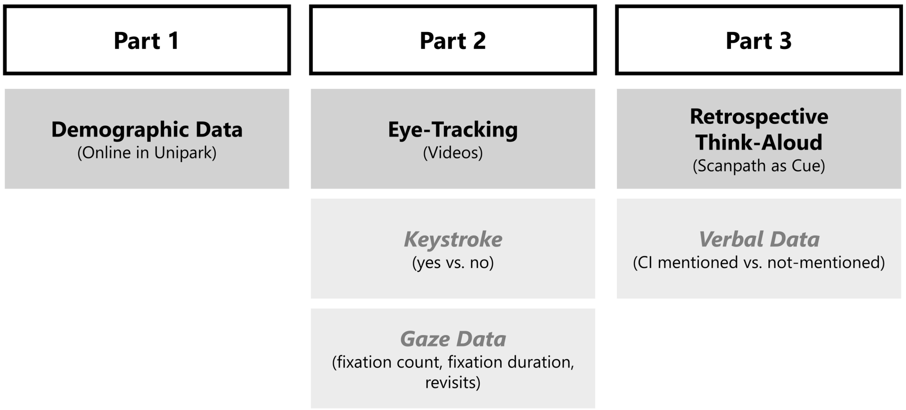

FIGURE 1
Design of the study.

TABLE 2 Specification of the disruptions in video A and video B.

Video	Type of disruption	Location	Accuracy keystroke *M* (*SD*)	Accuracy RTA *M* (*SD*)
A (duration: 1:29 min)	1. Striking yawning boy talking with neighbors	Back right	0.58 (0.50)	0.49 (0.50)
	2. Girl throws paper ball to another girl who is answering a teacher's question	Front	0.40 (0.50)	0.47 (0.50)
B (duration: 2:01 min)	3. Chattering pupil group	Back left	0.79 (0.41)	0.41 (0.50)
	4. Boys passing a slip of paper	Left	0.67 (0.47)	0.39 (0.49)
	5. Another chattering pupil group	Back right	0.73 (0.45)	0.33 (0.47)

Range of accuracy: 0–1.

Fusion, 120 Hz).[1] High-quality eye-tracking data were recorded for the participants (calibration accuracy: $M = 0.55$, $SD = 0.18$; calibration precision: $M = 0.35$, $SD = 0.18$).

The videos presented in the eye-tracking experiment were developed by "Toolbox Teacher Education" ("*Toolbox Lehrerbildung*") from the Technical University of Munich (Lewalter et al., 2020). They were based on scripted lessons from the 10th and 11th grades in the advanced track at a German secondary school ("*Gymnasium*"), covered topics in mathematics and informatics, and had already been used in preceding studies (Grub et al., 2022a,b). Each video was presented once during eye-tracking. The videos, in general, were selected based on events related to classroom management, audiovisual quality, and authenticity of the situation by three independent raters. For the aim of the present study, we selected two videos for a deeper analysis. The criteria for the selection of the videos were that they should consist of at least two CIs to increase the complexity of the scenario (Wyss et al., 2020), and approximately half of the participants should be aware of the CIs to give enough power for the analyses. The selected videos showed two or three CIs of classroom disruptions (for details, see Table 2).

2.4. Dependent variables and data analysis

2.4.1. Gaze data

An AOI-based evaluation of the eye-tracking data (fixation count, fixation duration, and revisits)[2] was performed; that is, the parameters were aggregated for the predefined AOIs. For this purpose, polygonal dynamic AOIs were determined deductively, including those that corresponded to the CI, that is, individual students or groups of students. The parameters were calculated for every CI in both video vignettes; therefore, each parameter was present for each CI.

2.4.2. Verbal data (RTA)

Using three general questions, participants were instructed to think aloud while watching their scan path-cued videos again ("What did you see?" "Why did you notice it?" and "How is what you saw relevant to the lesson?"); however, only the answer to the first question

1 We used a 24-inch display monitor (1080×1920), kept the distance between eye tracker and participants as identical as possible (approx. 65cm), and ensured uniform illumination. Before the recording itself, we conducted a 9-point automatic calibration followed by a validation to ensure data quality. The calibration was performed again if the 9-point automatic calibration failed.

2 The data were exported from Tobii with a Tobii I-VT (fixation) filter with a standard setting (I-VT classifier), i.e., a threshold from 30°/s.

was relevant for the present study. Participants could either verbalize a CI (1) or not mention it (0) in the RTA. Therefore, audio tracks from the RTA were transcribed verbatim. All the data were then read into MAXQDA 2022 and coded with respect to the descriptions of the CIs in the videos based on the master ratings (see Table 2). Coding was performed for each CI by two independent raters (the first author of this paper and an educational psychology student), with a satisfactory interrater reliability (Cohen's kappa) between 0.73 and 0.88.

2.4.3. Concurrent measure (keystroke)

Participants were instructed to watch the videos carefully and received the following instruction regarding the keypress: "If you notice something relevant, press the keyboard." Each CI was checked to identify whether a keystroke was recorded for it during the period in which the CI occurred. This keystroke defined whether the participant was aware of the CI and whether they had at least one fixation on that AOI. Therefore, each participant had either a keystroke score of 0 (not pressed) or 1 (pressed + fixation) for every CI.

3. Results

The analyses were calculated using SPSS IBM (version 29). An alpha level of 0.05 was used for the statistical tests. The analyses were conducted for each CI separately because the size and location of the AOIs could affect the values of the gaze parameters. Therefore, an aggregated analysis can lead to confounded results (Pappa et al., 2020; Holmqvist et al., 2022; Grub et al., in press).

3.1. Preliminary analyses and descriptive results

Because some previous studies have found effects of expertise on gaze behavior (see Grub et al., 2020, in press), we wanted to avoid possible confounding effects in our analyses. Therefore, we conducted MANOVAs for each CI with expertise as the between-subject variable and the eye-tracking parameters (fixation count, mean fixation duration, and revisits) as dependent variables. The means, standard deviations, and detailed results are displayed in Table 3. No statistically significant differences were found, so we removed expertise as a control variable in the subsequent analyses.

The descriptive results and the consistency regarding the accuracy of noticing the CIs using the two measurements (keystroke and RTA) are displayed above in Table 2. In Video A, around half of the participants reacted with a keystroke to the CI and mentioned it in the RTA. The consistency between the accuracy of the two measurements in Video A was moderate with Cohen's $\kappa = 0.46$ for CI 1 and $\kappa = 0.58$ for CI 2. In Video B, we found larger differences between accuracy by keystroke and accuracy by RTA: around 33–75% of the participants reacted with a keystroke, but only 33 to 41% mentioned the CI in the RTA, which led to low consistency values ($\kappa_{CI\,3} = -0.11$, $\kappa_{CI4} = 0.40$, and $\kappa_{CI5} = 0.20$).

3.2. Differences in gaze behavior regarding awareness

3.2.1. Concurrent measurement of noticing (keystroke)

A MANOVA was performed for each CI separately, with the concurrent measurement of noticing (keystroke yes vs. no) as the between-subject variable and the eye-tracking parameters (fixation count, mean fixation duration, and revisits) as dependent variables. The means, standard deviations, and detailed results can be found in Table 4. The omnibus test was significant for four CIs; therefore, the *post hoc* univariate ANOVAs were interpreted. Regarding *fixation count*, generally, participants who responded with the keystroke fixated on them more often. The difference was statistically significant for three CIs (CI 1, CI 2, and CI 4): $F_{CI\,1}$ (1,50) = 5.31, $p = 0.01$, $\eta_p^2 = 0.096$; $F_{CI\,2}$ (1,50) = 32.81, $p <. 001$, $\eta_p^2 = 0.401$; $F_{CI\,4}$ (1,50) = 11.82, $p = 0.001$, $\eta_p^2 = 0.188$. Regarding *mean fixation duration*, participants who noticed the CI fixated on it longer only in the case of CI 3: $F_{CI\,3}$ (1,50) = 4.60, $p = 0.02$, $\eta_p^2 = 0.085$. Regarding *revisits*, aware participants looked at the AOIs more often in CI 3 and CI 4: $F_{CI\,3}$ (1,50) = 4.62, $p = 0.02$, $\eta_p^2 = 0.085$; $F_{CI\,4}$ (1,50) = 4.61, $p = 0.02$, $\eta_p^2 = 0.084$.

3.2.2. Verbal measurement of noticing (RTA)

As before, a MANOVA was performed for each CI separately, with the retrospective measurement of noticing (CI mentioned in RTA yes

TABLE 3 Expertise and gaze behavior.

	Descriptive statistics *M* (*SD*)						Values of significance	
	Fixation count		Mean fixation duration		Revisits		*F ratio* (*p*)	η_p^2
Expertise	Expert	Novice	Expert	Novice	Expert	Novice		
Video A								
CI 1	22.58 (9.51)	18.54 (10.09)	0.41 (0.19)	0.42 (0.09)	7.27 (3.13)	5.73 (3.57)	0.90 (0.45)	0.05
CI 2[a]	7.44 (4.57)	9.50 (5.16)	0.45 (0.24)	0.48 (0.25)	1.76 (1.33)	2.11 (1.33)	1.05 (0.38)	0.06
Video B								
CI 3	43.27 (15.76)	39.04 (14.69)	0.33 (0.10)	0.32 (0.13)	8.70 (3.47)	7.96 (3.93)	0.61 (0.62)	0.04
CI 4	40.46 (15.68)	33.50 (18.51)	0.28 (0.08)	0.25 (0.08)	11.84 (3.54)	9.54 (3.83)	2.42 (0.08)	0.13
CI 5	39.54 (12.17)	38.85 (13.27)	0.43 (0.14)	0.41 (0.16)	11.04 (3.26)	10.77 (3.63)	0.13 (0.94)	0.01

[a]$N = 51$. An alpha error correction according to Bonferroni Holm was performed for each CI.

TABLE 4 Keystroke and gaze behavior.

	Descriptive statistics *M* (*SD*)						Values of significance	
	Fixation count		Mean fixation duration		Revisits		*F ratio* (*p*)*	η_p^2
Key-stroke	Yes	No	Yes	No	Yes	No		
Video A								
CI 1	**23.17 (9.77)**	**17.00 (9.19)**	0.43 (0.12)	0.40 (0.18)	7.07 (3.05)	5.73 (3.79)	**2.44 (0.04)**	**0.13**
CI 2[a]	**12.19 (4.01)**	**5.90 (3.75)**	0.42 (0.14)	0.50 (0.29)	2.00 (1.30)	1.90 (1.37)	**11.31 (<0.001)**	**0.42**
Video B								
CI 3	42.59 (13.62)	35.82 (19.97)	**0.34 (0.12)**	**0.26 (0.09)**	**8.88 (3.57)**	**6.27 (3.55)**	**6.17 (<0.001)**	**0.28**
CI 4	**42.17 (15.94)**	**26.29 (15.45)**	0.28 (0.09)	0.25 (0.07)	**11.60 (3.57)**	**8.82 (3.80)**	**4.83 (0.003)**	**0.23**
CI 5	41.50 (12.64)	32.93 (10.54)	0.41 (0.15)	0.43 (0.15)	11.50 (3.17)	9.29 (3.65)	2.07 (0.06)	0.11

[a]$N = 51$; *One-sided significance test. Significant values ($\alpha < 0.05$) are given in bold. An alpha error correction according to Bonferroni Holm was performed for each CI.

TABLE 5 RTA and gaze behavior.

	Descriptive statistics						Values of significance	
	Fixation count		Mean fixation duration		Revisits		*F ratio* (*p*)*	η_p^2
RTA	Yes	No	Yes	No	Yes	No		
Video A								
CI 1	22.96 (10.44)	18.58 (9.14)	0.41 (0.08)	0.41 (0.18)	6.92 (3.24)	6.15 (3.24)	1.16 (0.167)	0.069
CI 2[a]	**11.79 (4.91)**	**5.54 (2.61)**	0.42 (0.17)	0.51 (0.25)	1.96 (1.08)	1.96 (1.56)	**11.62 (<0.001)**	**0.432**
Video B								
CI 3	44.86 (14.82)	39.00 (15.32)	0.28 (0.08)	0.35 (0.13)	9.29 (4.36)	7.73 (3.11)	2.15 (0.05)	0.121
CI 4	**49.05 (15.31)**	**29.94 (14.03)**	0.27 (0.09)	0.27 (0.08)	**12.55 (2.70)**	**9.71 (3.95)**	**6.86 (<0.001)**	**0.304**
CI 5	**44.65 (13.61)**	**36.47 (11.53)**	**0.35 (0.09)**	**0.45 (0.16)**	**12.12 (4.00)**	**10.26 (3.01)**	**2.50 (0.04)**	**0.138**

[a]$N = 51$; *One-sided significance test; RTA: CI mentioned in the stimulated RTA protocol. Significant values ($\alpha < 0.05$) are given in bold. An alpha error correction according to Bonferroni Holm was performed for each CI.

vs. no) as the between-subject variable and the eye-tracking parameters (fixation count, mean fixation duration, and revisits) as dependent variables. The means, standard deviations, and detailed results can be found in Table 5.

The omnibus test was significant for three CIs. Therefore, the *post hoc* univariate ANOVAs were interpreted. Regarding *fixation count*, generally, participants who mentioned the CI in the RTA, fixated on them more often. The difference was statistically significant for three CIs (C1 2, CI 4, and CI 5): $F_{CI\,2}$ (1,48) = 32.34, $p < 0.01$, $\eta_p^2 = 0.403$; $F_{CI\,4}$ (1,49) = 22.01, $p < 0.01$, $\eta_p^2 = 0.300$; $F_{CI\,5}$ (1,49) = 5.05, $p = 0.02$, $\eta_p^2 = 0.093$. Regarding *mean fixation duration*, participants who noticed the CI fixated on it longer only in one case (CI 5): $F_{CI\,5}$ (1,49) = 5.10, $p = 0.02$, $\eta_p^2 = 0.094$. Regarding *revisits*, aware participants looked at the AOIs more often and statistically significant differences were found for two CIs (CI 4 and CI 5): $F_{CI\,4}$ (1,49) = 7.91, $p = 0.003$, $\eta_p^2 = 0.139$; $F_{CI\,5}$ (1,49) = 3.44; $p = 0.02$; $\eta_p^2 = 0.066$.

3.3. Differences in noticing regarding expertise

To validate the measurement keystroke and RTA for the assessment of noticing, we investigated whether experts responded to more CIs with a keystroke (Hypothesis 2a) and mentioned it more frequently in the RTA (Hypothesis 2b). A MANOVA was performed for each CI separately, with expertise (expert teachers vs. student teachers) as the between-subject variable and the two CI noticing variables (keystroke, RTA) as dependent variables. The means, standard deviations, and detailed results can be found in Table 6. No statistically significant differences were found for noticing the CIs, for keystroke or RTA. This means that experts and novices noticed the CIs equally.

4. Discussion

In the present study, we used a keystroke task and a stimulated RTA task to assess the noticing process of (novice) teachers and combine the two tasks with eye-tracking measurement (fixation count, fixation duration, and revisits as known parameters for awareness) as well as with expertise through methodological triangulation.

Regarding our first research question, we showed that aware participants who pressed the key (and had a fixation on the corresponding AOI) fixated on the AOI more often and had more revisits than non-aware participants. Comparable results could be found for the verbal task: participants who mentioned the CI in the

TABLE 6 Noticing and expertise.

	Descriptive statistics *M* (*SD*)				Values of significance	
	Keystroke		RTA		*F ratio (p)**	η_p^2
Expertise	Expert	Novice	Expert	Novice		
Video A						
CI 1	0.62 (0.50)	0.52 (0.51)	0.58 (0.50)	0.40 (0.50)	0.78 (0.23)	0.032
CI 2	0.38 (0.50)	0.44 (0.51)	0.50 (0.51)	0.44 (0.51)	0.38 (0.34)	0.016
Video B						
CI 3	0.85 (0.37)	0.72 (0.46)	0.50 (0.51)	0.32 (0.48)	1.52 (0.11)	0.061
CI 4	0.77 (0.43)	0.60 (0.50)	0.46 (0.51)	0.32 (0.47)	0.95 (0.20)	0.038
CI 5	0.81 (0.40)	0.64 (0.49)	0.35 (0.49)	0.32 (0.48)	0.89 (0.21)	0.036

*One-sided significance test. An alpha error correction according to Bonferroni Holm was performed for each CI.

RTA fixated on the AOI more and had also more revisits. Nevertheless, for both gaze parameters, this was statistically ensured only for three of the five CIs. A statistically significant difference in mean fixation duration was found for only one CI. Contrary to our hypothesis, the mean fixation duration for CI 5 was shorter for participants who mentioned the CI in the RTA. Therefore, Hypotheses 1a and 1b were only partially confirmed.

The findings that participants who were aware of the CI (reacted with a keystroke or mentioned it in the RTA) showed gaze behavior that corresponded to attention to a CI (more fixations, more revisits), is aligned with theoretical assumptions (Gegenfurtner et al., 2011; Holmqvist et al., 2011) and empirical evidence on the PV of teachers (Yamamoto and Imai-Matsumura, 2013; Wolff et al., 2016; Wyss et al., 2020). The partial lack of statistical findings can possibly be explained by the fine-grained analysis for each separate CI (Kaakinen, 2020). We decided against an aggregated analysis because the size and location of the AOIs can influence gaze parameters (Pappa et al., 2020; Holmqvist et al., 2022; Grub et al., in press) and therefore confound the results. Further research should take this into account.

Contrary to our hypotheses, there were no mean fixation duration differences between the aware and unaware participants. The studies of Wyss et al. (2020) and Yamamoto and Imai-Matsumura (2013), which showed longer fixation durations for the aware participants, had only one CI in their videos. In contrast, our videos had two or three CIs, so we cannot completely rule out an overlap. Especially in dynamic fields like teaching in a classroom, continuous monitoring is necessary to update what is going on. Therefore, participants may have used more scanning or monitoring gaze behavior, which is characterized by more and shorter fixations (Wolff et al., 2016; Grub et al., 2020; Huang et al., 2021), to detect everything that could be important. That participants show more monitoring gaze behavior, might be also an effect of the presentation mode: Minarikova et al. (2021), for example, in their study, compared the IN-mode (during class instruction with a mobile eye tracker) and the ON-mode (observation of the video of that instruction with a stationary eye tracker) and showed more monitoring gaze-behavior in the ON-mode. During the instruction (IN-mode), the teacher must monitor the classroom, but, for example, they must also interact with the students, whereas in the ON-mode, the task is mostly observation. To interpret the results of our study, the processes of monitoring the whole scene and focusing on single cues could have canceled each other out, what resulted in non-significant differences. This leads also to the question, whether fixation duration is an appropriate parameter for assessing the attentional focus because of its sensitivity for influencing factors like presentation mode or rather the task of the observation (see also 4.2).

Referring to our second research question, we found no differences between experts and novices in the accuracy of noticing, either in the keystroke or the RTA tasks. In many studies, experts have been better able to identify relevant cues of a dynamic scene (Lachner et al., 2016; Stahnke et al., 2016; Wolff et al., 2016, 2021; Boshuizen et al., 2020). Nevertheless, the expertise effect tends to occur in more complex conditions, when elaborated knowledge is needed. Stahnke and Blömeke (2021a), for example, showed expertise differences in perceiving potential disturbances only for partner work scenarios, and not for whole group scenes. Seidel et al. (2021) demonstrated an advantage in detecting the characteristics of students for expert teachers only for inconsistent student profiles; the authors also showed expertise differences only in the seatwork scene. These results suggest that the recognition of potentially disruptive situations may depend on the knowledge or expertise of the observer but also that the context matters. It may be easier to recognize relevant disruptive situations in whole group scenes—as were used here—than in other formats. This could be because salient visual impressions, such as movements, are easier to recognize via bottom-up perception processes, and the advantage of experts (namely, that they already have elaborate, flexible knowledge schemata that enable top-down perception) is not necessary for identifying disruptive situations. In addition, it may be easier for student teachers to recognize situations that they have probably actively experienced themselves as students (disruptive teaching situations) than to identify situations that represent, for example, cognitive activation, since this requires much more elaborated knowledge of educational science and didactics.

The heterogeneous results lead to questions concerning validity and the benefit of using keystroke and RTA to complement the measurement of noticing in the methodological triangulation of data. Despite only partially significant results regarding the eye-tracking parameters, we see the keystroke task as a promising addition to gaze-data in dynamic scenarios. By a keystroke, the researcher can infer that a participant has a conscious focus on a specific AOI at a specific moment, especially when the keystroke is combined with a fixation on that AOI (Crundall, 2016; Malone and Brünken, 2020). Nevertheless, we propose some important conditions for the validity of this inference: (1) The AOIs should be definable and not overlapping. If this is not possible, additional information should be gathered about the thoughts or visual focus of the participant (see also Section 4.2). (2) A given instruction about the task should be well considered due to its influence on the gaze behavior (Yarbus, 1967; DeAngelus and Pelz, 2009; Grub et al., 2022b; Martin et al., 2023) but also on reaction-based measurements such as the keystroke. In our task, the participants had the instruction, "If you *notice* something relevant, press the keyboard," which ensured the focus of attention in any given moment of an AOI, but instructions to press the button when the participant identifies that *a reaction is needed* (Moran et al., 2019) would also be useful. Further research on this is necessary and important.

The verbal data gained through RTA can give important insight into the thought processes of the participants and are, therefore, a useful additional source of information about the noticing process (Yamamoto and Imai-Matsumura, 2013; Wyss et al., 2020). Although, we used the replay of participants' gaze as a stimulus for the RTA to obtain higher validity data, a drawback of our design was the administration of the RTA after the observation of all the videos. We could not prevent oblivion or mixing up the videos by participants. Indeed, in the RTA protocols, we found, for example, several statements such as "Cannot remember why I pressed the button" or about the behavior of students visible in another video. In addition, an active reconstruction process by means of cues instead of reporting the thoughts during observation from memory cannot be avoided (*cf.* van Gog et al., 2005).

Additionally, in some RTA protocols, the verbal allocation to a specific student group was not clear enough to rate it as "mentioned" (for example, with statements such as "they are chattering," where it was unclear which students were being referred to in the use of "they"). This is also a possible explanation for the lack of consistency between RTA and the keystroke in Video B. To prevent these effects, the timespan between observing videos and gaining verbal data should be as short as possible. Furthermore, instructions in the RTA should be very clear (for example, "Name or describe the students you focused on"; see Yamamoto and Imai-Matsumura, 2013). Alternatively, the relevant part of what is being verbalized could be clicked on again during the RTA, either via touchscreen monitor or mouse click (depending on the technical requirements). In follow-up studies, it may also be worth considering a modification of the classic RTA toward a somewhat more guided semi-structured interview with the investigator, so that they could make follow-up inquiries about ambiguous statements to reduce later ambiguities.

The finding that awareness based on RTA verbalizations was generally lower than awareness via keystroke (see Table 2) could be due to the method of recording, namely the verbalization itself. Novice teachers, for example, have difficulties applying their knowledge and reasoning about noticed events (Schäfer and Seidel, 2015). Thus, it could be that they had already noticed the events (which can be seen in the keystroke) but they interpreted and verbalized the situation differently compared to our master rating (for more information, see Grub et al., 2022a,b). The experts, on the other hand, might have had difficulties in verbalizing what they actually saw because their knowledge was often rather implicit and so-called tacit, and therefore, was not available for introspection (Sternberg and Horvath, 1999). Tacit knowledge is typically reflected in eye movements "but is not necessarily available for conscious thoughts" (Kaakinen, 2020, p. 172), and therefore is not verbalizable. These are conceivable reasons why the CIs were assigned awareness more often via keystroke than RTA. Further research is therefore necessary to derive, for example, causal relationships.

4.1. Strengths and limitations

Our research has some clear strengths, but also some weaknesses. We used a very well-balanced experimental design with a comparatively large sample size. What is positive in comparison to the studies of Wyss et al. (2020) and Yamamoto and Imai-Matsumura (2013) is that our data collection had a significantly higher sampling rate (120 vs. 60 Hz) and a more accurate calibration procedure (nine-point vs. five-point calibration). Furthermore, we used videos with multiple CIs (two or three CIs vs. one CI in the mentioned studies) and two videos instead of one, which makes the data more accurate and multifaceted and thus slightly increases the external validity.

Another strength is the multi-methods approach, which allowed us to combine the different measurement methods for noticing and examine the validity of the keystroke and verbal data with gaze parameters, a so-called methodological triangulation with three different sources of information. In addition, by systematically analyzing *post hoc* verbalizations (RTA) and concurrent measures (keystroke) in conjunction with eye-tracking data (fixation count, mean fixation duration, revisits), this article represents one of the first methodological attempts in the research area of teachers' PV to combine and triangulate different data sources in order to mitigate the problems associated with the eye–mind assumption and eye-tracking research. Thus, this study lays a foundation for further systematic investigations based on it and represents a starting point for continuing studies.

Nevertheless, on top of the mentioned limitation regarding administrating the RTA protocols, the study has some drawbacks. Although we used standardized video samples, these were very short extracts of very standardized lessons in a frontal teaching setting with low complexity and very "usual" disturbances (Grub et al., 2020, 2022a,b; Grub, 2023). To recognize differences in competence, the situation or the focus to be observed should be more complex, because only then will the top-down-based perception typical for expertise become relevant, and thus, the differences between novice and expert teachers will become visible (Seidel et al., 2021; Stahnke and Blömeke, 2021a). If explicit investigations regarding differences in expertise are to be conducted, care should be taken to ensure that the material used is also suitable for this purpose, i.e., that a knowledge-based top-down perception is a prerequisite for successful PV.

4.2. Implications for further research

With the keystroke and RTA approaches, we were able to investigate two additional measurement methods for noticing, so providing more information about the location of attention than gaze parameters alone. Both approaches have their particular (dis-) advantages. A keystroke is an economic and non-invasive process-based method of assessing the spontaneous noticing process during an observation. Researchers should bear in mind, however, that with a keystroke alone, only information about the timepoint, but not about the location of the noticing process, can be inferred. For this, additional information from eye-tracking (fixation at the moment of the keystroke) or verbalizing is necessary. Another possibility for future research is a mouseover with a click to tag the attentional focus during observation; however, this can lead to distortion of the gaze behavior (Malone and Brünken, 2020). Therefore, the question remains open about what (creative) possibilities there are for matching eye-movement data relative to the two investigated variants, and whether there might be more suitable methods for triangulation.

The RTA is a less economical way of assessing what participants have seen during an observation and can lead to fabrication or oblivion despite a careful research design. Furthermore, it has higher requirements regarding verbalization skills for the participants. Nevertheless, RTA is an appropriate method to gain insight into the knowledge schemata as well as the characteristics of a situation as a basis for making inferences about professionals. In our study, we only rated a defined disturbing behavior if it was mentioned in the RTA. Additionally, it might be interesting to collect information on which concrete characteristics lead to the inference that a specific behavior is relevant. Seidel et al. (2021), for example, investigated whether (student) teachers can assess student profiles (struggling, uninterested, underestimating, etc.) accurately, asking participants which features lead to their decision. In our view, this is promising for gaining insight into the beliefs or intentions of (prospective) teachers. For example, the valuation of a behavior as disturbing depends on one's normative beliefs and expectations, the rules of the situation (e.g., frontal instruction vs. seatwork; Stahnke and Blömeke, 2021a), or the didactical aims of a teaching situation (McIntyre et al., 2017; Muhonen et al., 2021, 2023). Beyond that, however, many other conceivable factors can influence the relevance of an event and a participant's decisions and behavior; for example, what education the (student) teacher has enjoyed, generational effects, more conservative vs. liberal attitudes facing the teaching process (which could influence the estimation process), experience in dealing with disturbances, motivation, or (self-effective) handling of disturbances in one's own teaching practice.

Finally, we want to emphasize a well elaborated selection of eye-tracking parameters carefully derived from a theoretical foundation and the hypotheses of the research (Holmqvist et al., 2011; Carter and Luke, 2020; Grub, 2023). For example, the parameter fixation duration could be influenced by some conditions as the aim of perception (e.g., observing or interacting) or the presentation mode of the stimuli (e.g., ON mode vs. IN mode). As a parameter for attention, it is maybe not sufficient for dynamic tasks, when monitoring or scanning is needed (as observation in the classroom or a traffic scene to detect incidents or hazards). For assessing monitoring gaze behavior, the Gini coefficient as a measure of (un-) equal distribution (Cortina et al., 2015) as well as the gaze relational index (GRI) as a combined measure was used (Gegenfurtner et al., 2020b; Kosel et al., 2023b). The latter is calculated as the relation of fixation count and fixation duration, a lower value indicate a more equally distribution of gaze over the scene. It is an open question, if other combinations of parameters are suitable for assessing the focus of attention or other relevant perceptional skills. For future research, we also see the application of a person-centered approach as promising to combine different eye-tracking parameters as well as other methodological measures within a person to identify different profiles and take the heterogeneity of persons or situations into consideration (Bergman and Andersson, 2012; Hickendorff et al., 2018).

5. Conclusion

With the present paper, we create a first step toward the systematic elaboration of a methodological approach for triangulating eye-tracking data from (prospective) teachers by providing new insight into triangulating eye-movement data with concurrent measurement as well as *post hoc* verbalization. We were able to find heterogeneous results regarding the validity of the two triangulation methods: when considering eye movements and measures of noticing (RTA, keystroke), it is clear that conscious awareness is associated with increased monitoring of video footage (in particular, more fixations and revisits), but not for all CIs. In accordance with these findings, verbal data and concurrent measurements seem to be useful, albeit limited, ways to link eye movements to awareness. Furthermore, we did not find differences in attention between expert and student teachers, either in terms of verbal data or their behavioral responses. All in all, this type of research needs further systematic investigation and purposeful manipulation to ensure a more suitable resource-saving method of data triangulation for eye-tracking data that can be used in the medium term to examine teachers' PV. Only adequate methodological triangulation will allow valid conclusions to be drawn from eye-tracking data, and ultimately, they will be of great importance, especially in the long term, for applying study results to teacher education and training.

With regard to open science research, we would like to emphasize that our study is presented as transparently as possible: the study design was preregistered, our data are accessible for interested researchers, and regarding the eye-tracking procedure, as much information as possible is provided to make replication possible (e.g., information on calibration precision/accuracy, threshold filter, information on the generation of AOIs, etc. see Pappa et al., 2020; Holmqvist et al., 2022; Kosel et al., 2023b).

Data availability statement

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

Ethics statement

The studies involving humans were approved by Data Protection Officer, Saarland University. 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

AB: Conceptualization, Data curation, Formal Analysis, Writing – original draft. RB: Writing – review & editing, Funding acquisition. DL: Resources, Writing – review & editing. A-SG: Writing – review & editing, Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources.

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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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Training & prompting pre-service teachers' noticing in a standardized classroom simulation – a mobile eye-tracking study

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Numerous events happening in classrooms require a teacher to select important and filter out irrelevant information. This crucial and challenging skill is referred to as noticing. For noticing classroom management events pre-service teachers have a smaller knowledge base and little teaching experience compared to expert teachers. Supporting pre-service teachers in developing their classroom management knowledge and noticing skill is, thus, of great importance for teacher education. Previous research finds positive effects of interventions on teachers' noticing during video observation. To our knowledge, no studies depict noticing during teaching. We examined $N = 46$ pre-service teachers' noticing with regard to classroom management during classroom teaching in a quasi-experimental between-subjects design. Pre-service teachers' took part in a standardized classroom simulation after a classroom management training, with one group receiving prompting regarding evidence-based classroom management strategies before and during the classroom simulation and one group receiving only training. We also included a control group without classroom management training. To assess differences in pre-service teachers' noticing, the classroom simulation elicited comparable conditions, including standardized classroom management events and student behavior. Mobile eye-tracking as well as retrospective video observations were used to explore teachers' event-related and global noticing. Event-related noticing was assessed via count and accuracy of noticed classroom management events. Global noticing included objective parameters of teachers eye movements (visit/fixation counts and duration) onto the students in the standardized classroom simulation. The results show that training and prompting significantly affected pre-service teachers' event-related noticing, with both experimental groups making fewer target and time errors compared to the control group. No significant differences were found with regard to global noticing. This includes fixation and visit count and duration on students. Correlational analysis showed a positive association between higher noticing accuracy and share of fixations on students. This study expands upon previous empirical research using mobile eye-tracking to obtain objective measures of teachers' noticing. It sheds light on the relevance of knowledge for teachers' noticing during teaching. It also takes a first step toward understanding how pre-service teachers' noticing during classroom teaching can be promoted through fostering knowledge about classroom management through a training.

KEYWORDS

noticing, classroom management, mobile eye-tracking, preservice teachers, instructional support, simulation-based learning

1. Introduction

With reference to the concept of professional vision and noticing (Goodwin, 1994; Seidel and Stürmer, 2014; van Es and Sherin, 2021), teachers are able to selectively attend to classroom events relevant for students' learning and interpret them based on their professional experience and knowledge. Teacher noticing is primarily based on visual perception (Wolff et al., 2021). Thus, current studies use (mobile) eye-tracking to explore teachers' eye movements and thereby aim to obtain objective measures of teachers selective attention. They explore teachers' noticing during the act of their own teaching (in-action: e.g. Cortina et al., 2015) and on-action contexts, which refer to teachers observing their own or others' classroom interactions after the act of teaching (e.g., video analysis: Sherin and Han, 2004). However, most in-action studies using (mobile) eye-tracking apply exploratory expert-novice comparisons. As they mainly use experience (years of teaching) or formal qualifications as a marker for expertise (e.g., Cortina et al., 2015; van Driel et al., 2021), they allow for only broad conclusions about whether and how it is possible to promote teacher noticing. With regard to classroom management, which has been shown to be a key determinant of student achievement (Seidel and Shavelson, 2007; Hattie, 2009), the identification of relevant events appears to be particularly important. We set out to investigate how the acquisition and activation of classroom management knowledge through an intervention (classroom management training and prompting) might affect pre-service teachers' (PSTs') noticing during a standardized classroom simulation. With this we aim to explore the relevance of classroom management knowledge for teachers' noticing during teaching. Hereby, we focus not solely on measuring PSTs' noticing as assessed by aggregated measures of eye movements to students in the classroom (global noticing). We also explore the number and accuracy of identified classroom events (event-related noticing) in a standardized classroom simulation by coding simulation recordings and retrospective think aloud commentaries of PSTs' simulation.

In this way, we contribute to discussions about the relevance of using different measures to assess teachers' noticing. In addition, we underline the importance of examining cognitive processing when assessing visual attention in-action. Implications for teacher education are discussed.

2. Theoretical background

2.1. Theoretical considerations about teachers' noticing with regard to classroom management

A teachers' skill of attending to significant and ignoring irrelevant events has been widely discussed under the holistic concept of professional vision (Goodwin, 1994; Sherin, 2001; van Es and Sherin, 2021). It is differentiated into different subfacets (König et al., 2022), depicting how teachers attend to events or situations and how they interpret those based on specific knowledge structures (cognitive scripts) and distinctive professional experiences (see Wolff et al., 2021). Seidel and Stürmer (2014) specifically describe the facets, noticing (selective attention) and knowledge-based reasoning, as two interrelated processes. Defined as how teachers selectively attend to or "see," noticing here posits teachers' visual perception as a precondition for subsequent interpretations of classroom events (Wolff et al., 2021). In this study, we particularly focus on the noticing process and refer to the term noticing synonymous with selective attention. We further focus on teachers' noticing with regard to classroom management events (Gold and Holodynski, 2017; van Driel et al., 2021), as this seems particularly useful for teacher education. Classroom management is a key determinant of student achievement (Seidel and Shavelson, 2007; Hattie, 2009) and described as a central knowledge component of teachers' professional competence (Baumert and Kunter, 2013; Blömeke et al., 2015). Specific knowledge about efficient classroom management might entail behavioral aspects of teachers' monitoring, including teachers withitness. In accordance to Gold and Holodynski (2017) and Kounin (1970), monitoring encompasses preventive strategies (non-verbal and verbal). These strategies depict communicating awareness to every individual student while maintaining a group focus on the class (e.g., pausing and calling on pupils, who do not participate) and keeping an eye on any events in the class in order to efficiently intervene and prevent disruptions (e.g., signaling with their gaze that one is aware of students engaging in disruptive behavior & walking around the whole classroom). In this line, Kounin (1970) also refers to the technical terms of time error (i.e., teacher notices and reacts to the disruption too late) and target error (i.e., teacher notices and addresses the wrong pupil). The behavioral strategies of monitoring show a proximity to the construct of noticing. In that focusing their gaze, wandering around the classroom and maintaining group focus (Kounin, 1970) seem important strategies for being able to direct attention to significant events happening in the classroom. Wolff et al. (2021), describe withitness as integrated situational awareness that forms the basis for teacher noticing. Thus, we conclude that specific knowledge structures about monitoring influence how preservice teachers selectively attend to classroom management events.

2.2. Assessment of teacher noticing using (mobile) eye-tracking (videos)

Seidel et al. (2020) argue that teachers' gaze assessed by (mobile) eye tracking provides a suitable operationalization for the noticing process to add on previous models of teacher cognition and professional vision (see Seidel and Stürmer, 2014; Lachner et al., 2016). Eye movements are guided by both top-down (e.g., knowledge) and bottom-up (e.g., saliency) processes (Schütz et al., 2011). As quantifiable measures of perceptual activity they indicate what objects, persons or events are currently being consciously processed, suggesting (selective) attention (see eye-mind hypothesis, Just and Carpenter, 1980).

To operationalize the process of noticing, previous works not only assess teachers' gaze but also the identification of events through for example think aloud procedures (Stahnke and Blömeke, 2021). In this paper, we adopt these different approaches by differentiating and investigating both global- and event-related noticing (see Grub et al., 2022b: global and event-related gaze behavior).

Previously, both in- and on-action studies explore teachers' global noticing by investigating eye movement measures (e.g., fixation/visit count and fixation/visit duration, see Grub et al., 2020), onto different objects, areas or persons (e.g., students, materials, task-relevant areas) in a classroom (video) (e.g., on-action: Yamamoto and Imai-Matsumura, 2013; van den Bogert et al., 2014; Kosel et al., 2021; in-action: Smidekova et al., 2020; Huang et al., 2021a; Chaudhuri et al., 2022). Global noticing measures are characterized by the fact that they represent aggregated eye movements over a certain time sequence, i.e., video length or lesson time. Sometimes they are also converted into ratios as the gaze relational index (Gegenfurtner et al., 2020) or the Gini coefficient (Cortina et al., 2015). Studies exploring these eye movement measures are mostly based on the eye-mind hypothesis (Just and Carpenter, 1980). This assumption posits that recorded eye movements indicate what area or contents are currently being consciously processed, suggesting a connection between attention and fixation measures. However, these studies exhibit limitations as they neglect the role of covert attention/peripheral vision, shown in different real-world tasks (e.g., Malik et al., 2022; Vater et al., 2022). Hence, by exploring global noticing, it is usually hardly possible to draw conclusions about the succession of individual cognitive processes and, thus, the application of knowledge.

Many on-action studies investigate event-related noticing, which refers to the identification of classroom events in ones' own or others classroom video (e.g., Wolff et al., 2016; Stahnke and Blömeke, 2021; Wyss et al., 2021; Grub et al., 2022a,b). A classroom event is defined in terms of content, for example effective instructional quality characteristics. With regard to classroom management this might refer to classroom disruptions, e.g., a student throwing a paper airplane during class time. Measures of event-related noticing can include eye movements (e.g., time to first fixation) related to these specific events in a classroom (video). In addition, indicators such as the number and type of noticed classroom management events as indicated by the participant (e.g., Stahnke and Blömeke, 2021; van Driel et al., 2021; Grub et al., 2022a). Based on the latter measures, collected through (retrospective) think-aloud protocols/stimulated recall interviews (Minarikova et al., 2021; Stahnke and Blömeke, 2021; Wyss et al., 2021; Grub et al., 2022a), we are able to more validly draw conclusions about attention.

To our knowledge, in-action studies rarely explore event-related noticing. The few examples include studies by van Driel et al. (2023) and Minarikova et al. (2021). There are several reasons why this is the case.

First and foremost, it is exceedingly difficult to ensure comparability between classrooms and classroom management events. Huang et al. (2021a) and Cortina et al. (2015) studied paired teachers teaching the same classrooms. Goldberg et al. (2021) and Stürmer et al. (2017) looked at standardized teaching simulations. To control specific bottom-up influences on teacher noticing and draw well-founded conclusions about the relevance of knowledge as a driver of attention during teaching, one challenge remains, namely establishing standardized conditions in a classroom context. Other factors that influence attention also speak in favour of standardization. Alongside knowledge and experience, studies ascertain classroom characteristics, seating order, students' gender (Smidekova et al., 2020), cultural factors (McIntyre and Foulsham, 2018; McIntyre et al., 2019) and student behavior (Goldberg et al., 2021; Kosel et al., 2023) to influence teachers' selective attention during classroom teaching. The affordances of the activity setting (student-directed partner work vs. teacher-directed whole-group activities) might also be relevant for teachers' noticing both during teaching (Cortina et al., 2015; Chaudhuri et al., 2022) and while observing teaching (Seidel et al., 2020; Stahnke and Blömeke, 2021).

In a similar vein, validly assessing event-related noticing requires (retrospective) think-aloud protocols/stimulated recall interviews. For in-action settings, such methods seem more difficult. Huang et al., (2021a, p. 3) describe the reasons for this as twofold. On the one hand, it does not seem possible to ask teachers to report on classroom events during instruction. On the other hand, remembering and verbalizing noticed classroom events might fail due to the relevant information not being consciously available. Recent studies, however, explore possibilities for assessing event-related noticing in-action through retrospective think-aloud protocols (Cortina et al., 2018; Minarikova et al., 2021; van Driel et al., 2022) and hand-signaling during instruction (van Driel et al., 2021).

In conclusion, using standardized classroom contexts and think-aloud approaches seems an inevitable step for in-action research in order to explore event-related noticing and the relevance of knowledge that guides the identification of classroom management events.

2.3. Knowledge and teaching experience as prerequisites for teachers' noticing

It is theoretically assumed that teachers' noticing is influenced by knowledge, stored as scripts in mind (Lachner et al., 2016; Wolff et al., 2021). Due to their lack of professional experiences in a classroom context, novices knowledge structures are limited compared to experts, who posses elaborate knowledge about classroom events as they were previously exposed to numerous classroom situations (Wolff et al., 2021, p.138). Comparisons of experts' and novices' eye movements are a common approach to support this assumption and understand teachers' noticing. Some eye-tracking research looking into global noticing indicates that novice teachers compared to experienced teachers differ greatly in how they use their gaze (e.g., Cortina et al., 2015), while others find few or distinctive differences within individual teachers (e.g., Smidekova et al., 2020; van Driel et al., 2021, 2023; Chaudhuri et al., 2022). Nevertheless, two central differences can be identified. Teachers with more experience tend to use their gaze more efficiently, similarly as in other fields of expertise, with shorter fixation durations and a higher number of fixations on task-related areas. This indicates improved information processing (Gegenfurtner et al., 2011). In addition, more experienced teachers show a selective focus of attention onto individual students and distribute their attention more evenly across (more) students (van den Bogert et al., 2014; Cortina et al., 2015; Dessus et al., 2016; Stürmer et al., 2017; Huang et al., 2021a,b; Kosel et al., 2023). Some previous studies using the Gini coefficient (GC), a statistical measure of unequal distribution (Cortina et al., 2015; Dessus et al., 2016), support this assumption. The Gini coefficient of novice teachers, in mean between 0.32 and 0.34, (Cortina et al., 2015; Dessus et al., 2016) indicates more difficulties in distributing attention equally. Some studies also focus event-related noticing. During the video observation of partner work compared to whole group scenes, Stahnke and Blömeke (2021) found expertise differences with regard to the frequency of noticed events. In contrast, van Driel et al. (2021) find teachers with different expertise levels noticing almost the same number of salient CM situations during teaching.

Based on these empirically found differences, expertise research reflects that top-down drivers (e.g., knowledge and experience) play a greater role for expert teachers compared to novices than bottom-up attention (e.g., directed by salient features in the classroom). With regard to teaching, this might mean that the selective attention by experienced teachers is more intentional (Haataja et al., 2019, p. 1). This is argued with respect to research on teachers' noticing during the act of teaching (i.e., in-action: e.g. Haataja et al., 2020; Goldberg et al., 2021; Huang et al., 2021a) and studies exploring it while observing own or others' classroom videos (i.e., on-action: e.g. Seidel et al., 2020; Stahnke and Blömeke, 2021; Grub et al., 2022b). Both contexts share the relevance of knowledge as a top-down driver of teachers noticing.

2.4. Promoting teachers' noticing using training and prompts

Based on expertise research, Wolff et al. (2021) describe a link between expert and novice teachers' different levels of classroom management knowledge and their visual processing of classroom management. They, thus, describe the importance of considering the role of classroom management scripts (Wolff et al., 2021), when designing training activities. The eye-tracking study by Grub et al. (2022a) supports this notion, as prospective teachers with higher knowledge more accurately noticed classroom management events. They detected more events related to classroom management and identified those faster (Grub et al., 2022a). In order for novice teachers to improve their noticing of classroom management events it, thus, seems useful to consider how to promote and activate knowledge about classroom management.

However, findings about general differences between expert and novice teachers' noticing can only be used to infer teacher education to a limited extent on how novices might develop expert-like approaches. The previous findings do not provide concrete information about how to promote novice teachers to activate and apply existing knowledge during noticing. Because knowledge is often indirectly assessed via teaching experience (years of teaching) (e.g., Cortina et al., 2015; van Driel et al., 2021) and expert teachers show more elaborate scripts, organized around professional experiences (Lachner et al., 2016), it is also more difficult to draw conclusions about direct effects of knowledge onto teachers' noticing. Expanding upon previous expert-novice noticing research, investigating concrete possibilities to promote and activate knowledge as a top-down driver of PSTs' noticing, hence, seems an interesting next step.

For this purpose, video-based research, relying on verbal reports and vignette tests, already reveals positive effects of interventions (e.g., trainings, instructional support) for supporting PSTs' noticing (Santagata et al., 2021; König et al., 2022). Trainings with regard to classroom management knowledge and video observation over several seminar sessions improved pre-service teachers noticing skills (Gold et al., 2020; Weber et al., 2020). Also shorter trainings (around 60–90 min) have shown positive effects on teacher noticing, in that pre-service teachers attend to more relevant events during video observation (e.g., Martin et al., 2022; Schreiter et al., 2022). For example Schreiter et al. (2022) included preceding knowledge training to examine the identification of difficulty-generating elements in a mathematic task. The experimental group with knowledge training identified more relevant task features and evaluated them correctly at a higher rate than the control group, suggesting a positive influence of specific knowledge components.

For scaffolding the application of previous knowledge and developing complex skills, also prompts have been shown to be effective tools (e.g., Hilbert et al., 2008; van der Meij and de Jong, 2011; Chernikova et al., 2019). In general, they help learners process information and support learning (e.g., Ifenthaler, 2012; Wong et al., 2021). They range from general instructions or questions to very precise and specific ones (Bannert, 2009, p. 139). Specifically with regard to perceptual processes, instructional cues (visual or verbal) during an activity, might direct attention to relevant areas (see de Koning et al., 2009). In this line, eye-tracking research, in general, shows that tasks or cognitions associated with previously acquired knowledge scripts and experiences, influence attention, altering eye movement measures (see Henderson et al., 2007; DeAngelus and Pelz, 2009; Glaholt et al., 2010; Gilbert and Li, 2013; Brams et al., 2019; Papesh et al., 2021). Facilitating medical students progression of eye movements and interpretations to be more "expert like" has successfully been done through training and cueing attention with experts eye movements or verbal guidance (e.g., training: Jarodzka et al., 2012; Kok et al., 2016, cueing during task completion: Chetwood et al., 2012, Leff et al., 2015).

Although teacher noticing research often uses prompts for guiding video analysis (e.g., van Es and Sherin, 2002), effects of different types of prompts on teachers noticing have seldom been studied in this domain (Martin et al., 2022). First eye-tracking studies with regard to teaching now tackle the question of how to promote expert-like noticing while observing classroom teaching by using prompts. A recent study by Grub et al. (2022b) implemented prompts in the form of a short general vs. specific instruction and showed that a specific task instruction seems to influence fixation and visit count (global noticing) among both novice and experienced teachers under specific circumstances (small effect). Additionally, Schreiter et al. (2022) investigated teachers' event-related global noticing of difficulty-generating elements in a mathematic task. More efficient visual processing with regard to task-relevant areas of interest were observed in the form of higher fixation counts, transitions and average fixation durations in the prompted group (Schreiter et al., 2022). The prompted group identified more relevant task features, suggesting a positive influence of prompting (Schreiter et al., 2022).

Summing up, all the studies explore how knowledge acquisition and activation directly affects teachers' noticing only during video observation. Thus, expanding upon previous on-action noticing research and investigating if it is possible to promote knowledge, as a top-down driver of PSTs' noticing in-action seems a promising next step.

3. Aim & research questions

The current study aims to better understand teachers' noticing and close the research gap as follows:

- First, mobile eye-tracking is rarely used to explore teachers' eye movements during teaching, but instead focuses on classroom video observation (on-action).
- Secondly, even when eye movements are assessed during teaching, research focuses on expert and novice comparisons and the

exploration of global noticing without considering teachers' accompanying cognitions. The studies seldom explore event-related noticing due to the lack of standardization and experimental control.

- Thirdly, in terms of significance for teacher education, hypothesis-driven designs that investigate how (prospective) teachers might learn or be triggered to successfully apply their classroom management knowledge in order to improve their noticing are scarce. Few center on teachers' noticing during classroom video observation.

We address these desiderata and apply a quasi-experimental design to explore how a classroom management training and additional prompting affects PSTs' noticing during a standardized classroom simulation. Specifically, on the one hand, we investigate to what extent PSTs are able to apply and activate evidence-based knowledge about classroom management strategies and with that practice more or less efficient noticing of classroom management events. We thus aim to provide new insights into possibilities to promote noticing during teaching in teacher education. On the other hand, we explore the potential association between two different operationalization of teachers' noticing previously reported as indicators of expertise, and explored both in in- and on-action contexts.

We expect certain eye movement patterns across our experimental groups, differing with regard to knowledge activation. We hypothesize that the experimental groups with more knowledge about classroom management use their gaze more intentional (i.e., more top-down selective attention). Hence, they show more efficient global and event-related noticing during teaching. We address the following research questions and hypotheses:

Research question (RQ):

RQ 1.1: (How) does a training and prompting affect PSTs' noticing as assessed by their global noticing of students?

Hypothesis 1.1a: Trained and prompted PSTs have a higher percentage of visits/fixations and shorter mean fixation durations/visit durations on students in the classroom. The group of prompted and additionally trained PSTs shows the highest percentage of visits/fixations and shortest mean fixation durations/visit durations on students in the classroom.

Hypothesis 1.1b: Trained and prompted PSTs distribute their attention more evenly across the seven simulated learners in the classroom and thus have a lower Gini coefficient (GC) with regard to visit count and duration. The group of prompted and additionally trained PSTs shows lowest Gini values.

RQ 1.2: (How) does a training and prompting affect PSTs' noticing as assessed by their event-related noticing of classroom management events?

Hypothesis 1.2: Trained and prompted PSTs exhibit a higher count and accuracy in noticing classroom management events compared to the control group. The group of prompted and additionally trained PSTs shows the highest noticing accuracy and event count.

RQ 2: To what extent is event-related noticing associated with global noticing of students?

Hypothesis 2: We expect both measures to be affected by more knowledge as a top-down driver. According previous hypotheses, we tentatively assume fixations and visit count to correlate positively with noticing accuracy and count of noticed events. Fixation and visit duration and Gini values we expect to correlate negatively with noticing accuracy and noticed events.

Our findings on the effects of a classroom management training and prompting teachers' noticing during teaching can provide information about whether (and how) it is possible to promote teachers' noticing. By adopting the differentiation (Grub et al., 2022b) between global and event-related noticing, we seek to bridge the gap between previous in- and on-action research. As we assess event-related noticing in an in-action setting, we are able to compare previous results of on-action research and investigate associations with previous eye movement measures used in real classrooms. The results, can advance our understanding of event-related noticing in in-action settings and further inform theory of teacher noticing.

4. Materials and methods

4.1. Design & participants

N = 52 PSTs (75% female) voluntarily took part in our eye-tracking study and participated in a standardized classroom simulation. All were enrolled in a teacher education program at Leibniz University Hannover, Germany. 34.6% of the PSTs studied secondary education and 65.4% aspired to teach special education. All study participants were completing master's degrees, with total semester counts (including bachelor's degrees) of $M_{semester} = 7.1$ ($SD_{semester} = 1.8$). The mean age was 24.9 years, with a standard deviation of 3.5 years. We pre-defined exclusion criteria for eye-tracking recordings as a gaze sample percentage of 80% or higher. We excluded six PSTs due to less gaze sample percentage. For the remaining data, we had a mean gaze sample percentage of 94% (SD = 3.84%); hence, one or both eyes were detected during 94% of the recording duration on average.

The study applied a quasi-experimental design displayed in Figure 1. It included one control group (CG) and two experimental groups: EG-T (experimental group with training) and EG-TP (experimental group with training and prompting). Both experimental groups received a training; one (EG-TP) additionally received prompting regarding evidence-based monitoring strategies. PSTs enrolled in three seminars were randomly divided into the two EGs. A fourth seminar formed the CG. PSTs in the CG took part in the simulation before learning about classroom management.

4.2. Standardized classroom simulation (TeachEye-ClasS)

The simulation "TeachEyeClasS" was embedded in four university courses on planning teaching practice and classroom management. In contrast to the real classrooms explored in previous studies, our standardized classroom simulation elicited comparable conditions for studying teacher noticing. It is a complexity-reduced and authentic approximation-to-practice (Grossman et al., 2009) developed for training and assessment purposes (Telgmann & Müller, in

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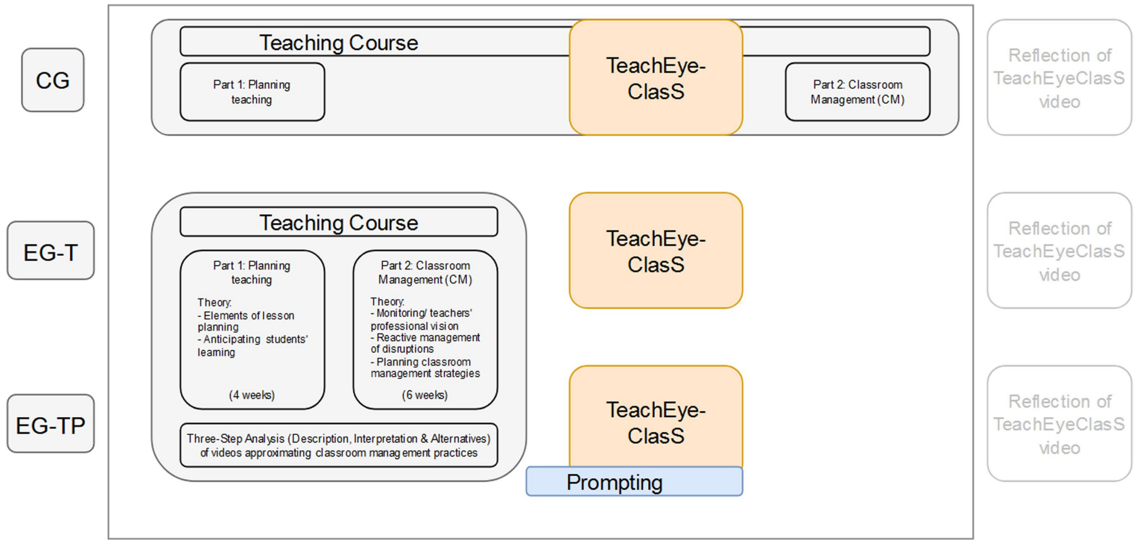

FIGURE 1
Study design. EG-T = Experimental group with training; EG-TP = Experimental group with training and prompting; CG = Control group.

preparation). PSTs' instruction during the 20-min simulation was based on a predefined lesson plan about a general topic in a 10th grade classroom. The lesson topic focused on the overarching theme of sustainability, specifically the introduction of two product labels, as a strategy for sustainable purchasing. This lesson was situated in the context of planning a sustainable class trip. As many previous studies focus on teacher-centered settings, we included both a teacher-led activity (~10 min) and a student-led activity (~10 min) within the lesson plan. We tried to establish a similar level of bottom-up attention for all PSTs by standardizing the occurrence of bottom-up drivers (e.g., student behavior and classroom management events). The simulation comprised the same set of seven pupils, played by trained student actors. The classroom seating order was standardized. Fourteen relevant classroom management events in the form of slight (e.g., looking out the window) and salient disruptions (e.g., talking loudly) were predefined (see Figure 2; slight events are shown in a grey box, salient in a blue circle). For each disruptions we pre-defined a certain time frame (e.g., minute 1–2) where it occurred, it was bound to the order of disruptions and foremost the didactic actions of the teacher (e.g., a disruption occurred, when the teacher introduced the first task). Additionally, we assigned the similar count and level of disruptions to both the teacher-led and student-led activity. The standardization also included the reactions of all other pupils to the relevant events. Thus, all PSTs faced the same challenging classroom management events, which require selective attention and not (over-) focusing on some students.

4.3. Experimental variation: training & prompting

Presuming that classroom management knowledge helps teachers identify and interpret visual information faster and more accurately (Wolff et al., 2021), we used a teaching course at university to prepare PSTs' to notice classroom management events and focus on students. The teaching course included 13 weekly meetings that were taught by the same two lecturers. They were phased into two course blocks, one on planning effective teaching and a second one focusing on classroom management (see Figure 2). Course content was divided between lecturers. Part 1 included repeating content about elements of lesson planning and how to anticipate students learning at the planning stage (e.g., setting appropriate learning goals). In this first part of the course all three groups applied their knowledge by planning a lesson with the similar learning goal and the same learning group of TeachEyeClasS. Part 2 focused on promoting specific classroom management knowledge for around 10.5 h and comprised video analysis homework in which students applied classroom management knowledge in an on-action setting (observing others' classroom management). Specific knowledge parts entailed classroom management strategies depicting rules and routines (Evertson and Emmer, 2012) and reactive management of disruptions (Ophardt and Thiel, 2013). Also how these strategies affect student behavior and learning. A focus was set to preventive strategies of teachers' monitoring (non-verbal and verbal) (Kounin, 1970; Gold and Holodynski, 2017) and how PSTs can use and plan these strategies for teaching. In the following, we refer to this intervention as training.

Accordingly, we presumed that PSTs in both experimental groups have specific knowledge about classroom management, but might not use it during the classroom simulation. Activating classroom management scripts might then help to elicit/evoke more knowledge-based (i.e., top-down) attention. To activate the respective cognitive scripts, we included specific cognitive prompts. In the domain of writing research and the use of learning strategies, cognitive prompts encouraging reflection on certain aspects of a topic have shown to be particularly effective learning aids (e.g., Glogger et al., 2009).

While preparing for the simulation in advance, we asked PSTs in EG-TP to remember and note down effective monitoring strategies within the standardized lesson plan. In addition, two events were added to the lesson plan and the PSTs were asked to plan effective monitoring strategies during these specific events (see Figure 3). To

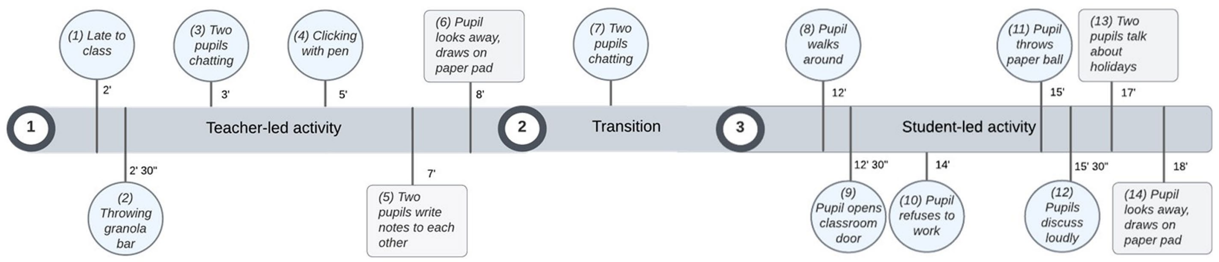

FIGURE 2
Description of classroom management events – disruptions within the simulation and approximate timing of occurrence. Slight events are shown in a grey box. Salient events are shown in a blue circle.

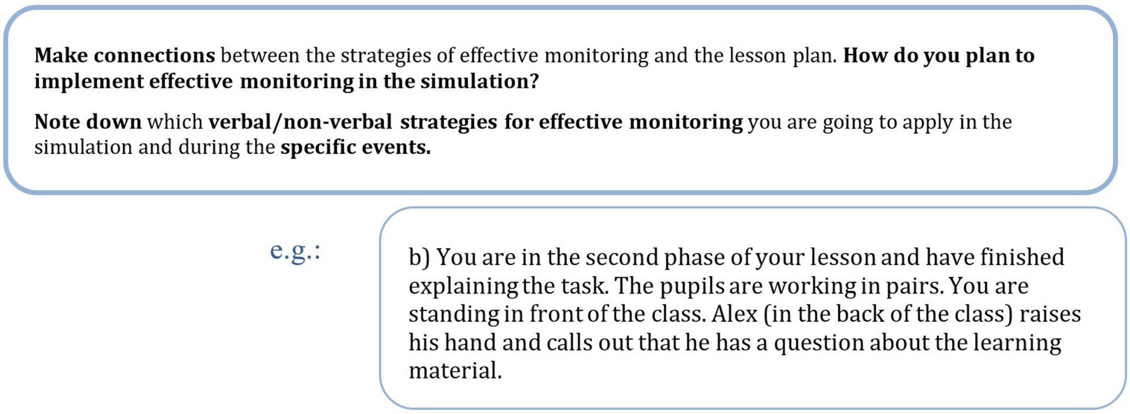

FIGURE 3
Cognitive prompt to activate classroom management scripts before the simulation.

activate classroom management scripts right before and during the simulation, an additional prompt card, shown in Figure 4 and displaying effective monitoring strategies, was given. The PSTs were instructed to implement the strategies and to put the prompt card on the teacher's desk during the simulation.

4.4. Study procedure

After the classroom management course (control group, respectively, after part 1 of the course) we were interested in assessing PSTs' cross-subject, general pedagogical knowledge (GPK) including their classroom management (CM) knowledge. For this, we used the short version of the Pedagogical Instructional Knowledge (PUW) test by König and Blömeke (2009, 2010), which was developed as part of the TEDS-M project. The test measures declarative and procedural knowledge across five dimensions: structuring lessons, motivation, dealing with heterogeneity, classroom management and assessing performance (König and Blömeke, 2009). The short version of the tests consists of 18 test items with either a closed or open response format. Specifically with regard to the dimension of classroom management, the test entailed four items (one open, three closed format) with regard to classroom management (e.g., planning aspects of concrete teacher behavior), effective use of teaching time (e.g., use of rules and routines) (König and Blömeke, 2009).

Further we used a questionnaire to assess self-efficacy (Schwarzer and Schmitz, 2002), socio-demographic data, semester count, experience in school contexts (i.e., internships, working as a substitute teacher) and extracurricular experiences with pedagogical references (e.g., club work).

The standardized lesson plan was given to the PSTs ten days before the simulation to allow them to get acquainted with it. We also provided pictures of the classroom and instructional materials placed in the room in advance. Other information included a detailed description of the group of learners (seven students). To ensure equal prior knowledge of the learning group and the topic to be taught, we proceeded as follows in selecting and implementing the topic of sustainability prior to the simulation. The selection of the topic in the context of sustainability was preceded by an investigation of the German curricula. We identified this topic as interdisciplinary and relevant in several subjects. To further ensure that the students enter the simulation with the same content-related prerequisites, all three groups received information material on the topic and learning goal. Furthermore, before taking part in the simulation we already presented this topic to the PSTs. In part one of the course on planning effective teaching, all three groups (including control) planned a lesson with the similar learning goal and the same learning group of TeachEyeClasS. This was also done to reduce cognitive load during the simulation, as our PSTs had limited practical experiences.

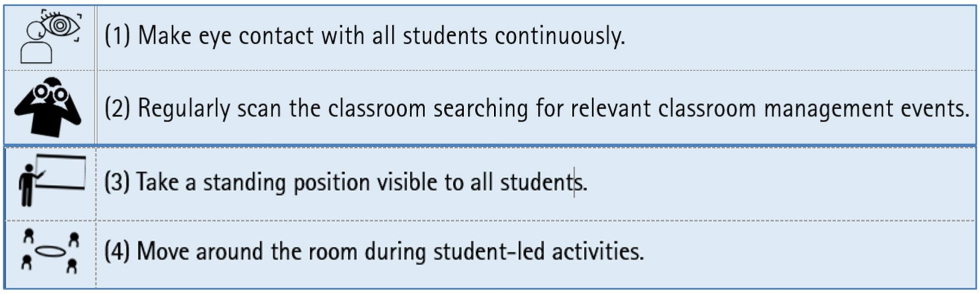

FIGURE 4
Specific prompt to activate classroom management scripts during the simulation.

Instructions were given to participants before the simulation while the equipment was being set up. To familiarize themselves with the equipment, the PSTs walked to the simulation room with the mobile eye-tracking glasses on. The PSTs also got the chance to see the classroom and locate instructional materials. After this, a one-point automatic calibration followed by a 3-point validation in the classroom was implemented to ensure data quality. The 3-point validation included three points within the classroom at three different distances. If calibration was not valid, the research assistant recalibrated until a satisfactory level was achieved. After successful calibration, the PSTs were asked to leave the room again. Following an acoustic signal (imitating a school bell), the simulation started and the PSTs entered the room. A research assistant filmed the simulation, ended it after approximately 20 min and escorted PSTs back to the preparation room to fill out a post-questionnaire about the simulation authenticity and cognitive load. The PSTs were also asked to hand in their commented lesson plan or notes used during TechEyeClasS. We collected these to retrace the use of prompts (see Figure 3) for the EG-TP.

Around ten days after the simulation (similar to Cortina et al., 2018), the PSTs in EG-T and EG-TP were asked to recall the simulation and retrospectively comment on their gaze video online. For the control group, this time frame was around three weeks longer. The PSTs observed their teacher gaze video via an online learning platform. They were able to stop their simulation video at relevant time stamps and interactively comment on it. The task given was the following: "Comment on your own mobile eye-tracking (MET) video using the interactive comment box next to the video as if you were thinking aloud. Recall the simulation again and indicate relevant events with regard to classroom management during the simulation. When did you notice a pupil who had problems following the lesson due to difficulties with content or motivation? And (possible) disturbances?"

Hence, all PSTs indicated where they noticed classroom management-related events (see Figure 5). After submitting their commentary, they were further asked to conduct a systematic video observation. Here, the PSTs conducted a three-step analysis describing, giving reasons for and generating alternative courses of action for all noticed classroom management events during the simulation. All PSTs were familiar with this form of analysis, as they had analyzed others' videos during the course.

4.5. Apparatus

Eye movements during the classroom simulation were recorded using Tobii Glasses Pro 3 at a sampling frequency of 50 Hz. Its technique includes corneal reflection and dark pupil tracking (4 sensors, 2 per eye) with scene camera resolution of 1920 × 1,080 pixels at 25 frames per second. The field of view of the scene camera was 95° horizontal, 106° diagonal and 63° vertical. The frame dimensions were 153 × 168 × 51 mm. The glasses include a reported accuracy by the manufacturer of 0.6°. The software used for recording was Glasses 3 (1.9.4). We standardized the eye-tracking conditions for all participants (same room, darkened windows, same ceiling light). In doing so, we reduced changes in illuminance over the course of the measurement and across participants. We used corrective lenses if participants had visual impairment and no contact lenses. The recording environment was a typical seminar room, set up to look like a school classroom.

In addition to the eye-tracking, we used two other cameras to record the scene and provide additional classroom footage for later coding: one in the back of the class, following the teacher (teacher camera: TC) and another stationary camera positioned in the front of the class (wide angle, student perspective, SC). The mobile eye tracker (Tobi Glasses Pro 3, 50 Hz) recorded the teachers' field of vision, resulting in a teacher gaze video.

4.6. Measures of PSTs' global and event-related noticing

In a first step, to answer RQ 1.1, we explore aggregated measures of eye movements as markers for teacher noticing during teaching. In doing so, we deliberately refer to global noticing (RQ 1.1) to stress the fact that this measure allows us to objectively capture PSTs' visual focus onto different objects in the classroom. As aggregated measures of eye movements are always a result of preceding cognitive processes (i.e., fixation count on one area of interest over the entire period of the simulation), we conclude that they in some way reflect teachers' noticing. In a second step, to assess teachers' event-related noticing (RQ 1.2) in a similar way as previous on-action research and account for covert attention/peripheral vision, we explore trained observers' coding of PSTs' gaze videos and retrospective video commentary and

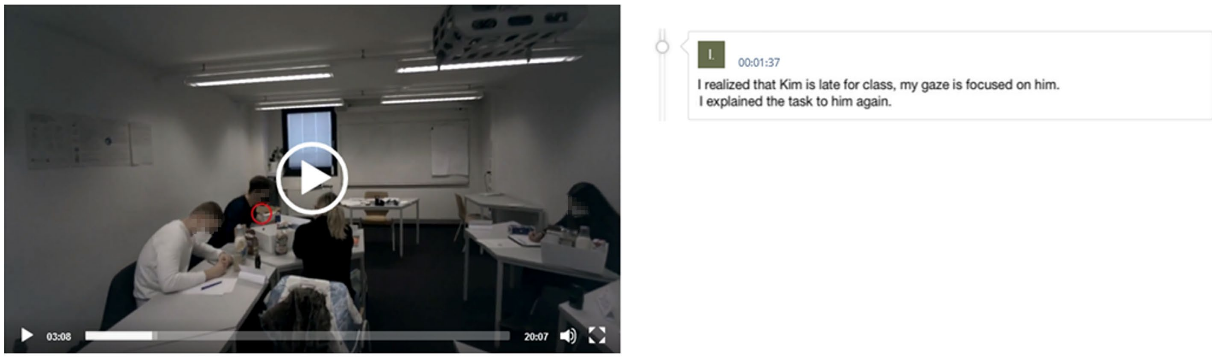

FIGURE 5
Example of PSTs' retrospective commentary on their own gaze video.

observation. Measures and procedures for coding and analysis are described below.

4.6.1. Assessment of global noticing (RQ 1.1)

4.6.1.1. Coding of eye-tracking data

Prior to the eye-tracking analyses, we defined areas of interest (AOIs). A wide-angle image of the standardized classroom simulation was first used to pre-define relevant semantic AOIs. Similarly to previous research (e.g., Stürmer et al., 2017; Huang et al., 2021a; Chaudhuri et al., 2022), we deductively developed AOIs: seven individual students; teacher & student material, lesson plan, prompt card as task-relevant objects and task-irrelevant objects: student & teacher desk, other objects and missing data. In order to observe differences in PSTs global noticing, we explore eye movement measures previously shown in expert-novice comparisons (RQ 1.1). Thus, in this study we only consider individual student AOIs and aggregated those to form the variable $AOI_{student}$. Figure 6 shows the relevant section of the screenshot used for data analysis in this study.

Instructions for coding the eye movement data included manually mapping all data onto the classroom image using the IVT-Attention Filter (velocity threshold parameter set to 100 degrees/s) in Tobii Pro Lab (Version 1.181.37603). In the few unclear cases (i.e., blurry frame, gaze outside the field of view of the scene camera), the coder was instructed to code the category "missing data." Gaze mapping was conducted, starting when the PST entered the simulation room and ending when simulation was interrupted after approximately 20 min.

One person coded all eye-tracking data in randomized order, while a second coder additionally coded 20% of the eye-tracking data ($N = 10$ videos). The first coder held a bachelor's degree and the second coder a master's degree in teacher education (first author). Both had experience collecting eye-tracking recordings in classroom settings. The coders received training on manual mapping in a half-hour training session with video material from a pilot study depicting a similar recording environment, classroom setting and AOIs. For the semantic AOI coding scheme we found good inter-coder agreement. It ranged from 88 to 94% with an average of 91%.

4.6.1.2. Eye movement measures

As previous expertise research indicates two central expert-novice differences, with experts showing more selective attentional focus on students and more even distribution of attention across (more) students, we explore the following eye movement measures. The ratio measure of the Gini coefficient (GC) (Cortina et al., 2015), mean fixation duration in milliseconds (ms), and percentage of fixation count on the aggregate $AOI_{student}$. For in-action studies some authors choose measures less sensitive to the eye movement event detector like visits and average dwell time (Smidekova et al., 2020, p. 6). Hence, we also report on visit duration in milliseconds (ms), and percentage of visit count on $AOI_{student}$. The GC is based on the fixation/visit count and duration for each individual student AOI during the whole video recording. A lower value indicates a more even distribution of attention (0 = perfectly equal distribution, 1 = one student gets all the attention). The reported results include a corrected Gini coefficient. In addition to fixation measures, we also examine the less sensitive measures of visit count and average dwell time/visit duration, similarly to Smidekova et al. (2020).

4.6.2. Assessment of event-related noticing (RQ 1.2)

4.6.2.1. Coding of video and retrospective commentary

To analyse the PSTs' event-related noticing, we collected the video from the student and teacher cameras, gaze video (recording of the mobile eye tracker) and PSTs' retrospective commentaries and systematic observations of their gaze video done online after participating in the simulation. To expand upon previous findings, we assess event-related noticing both in terms of the count of noticed events and qualitatively score PSTs' noticing accuracy. For this, trained observers assessed PSTs' event-related noticing based on their (gaze) videos and their retrospective commentary and observations. This procedure combines two advantages. Coding teachers' mobile eye-tracking video with gaze overlay (i.e., fixations displayed in the video) provides objective feedback about PSTs' noticing without manually coding PSTs' eye movements. In addition, consulting the PSTs' retrospective commentary and video observation allowed the observers to retrace accompanying cognitions. With coding based on all three video perspectives (teacher gaze, teacher and student cameras), we were able to ensure that the beginnings of all classroom management events (even if they were not in the teacher's field of view) appeared on the video recordings and could be used to assess noticing accuracy. We based our decision to include all video

FIGURE 6
Defined areas of Interests for individual students.

perspectives on a pilot study. There, effects of different video perspectives on the assessment of classroom management were found (Telgmann et al., in preparation). The second coding process for assessment of event-related noticing encompassed a three-step process shown in Table 1. The first author of this paper coded all video data in a randomized order. A research assistant again double coded 20% of the video data. Video coding was carried out using the software interact (Mangold International, 2020). To confirm reliability, we calculated the inter-correlation coefficient (*ICC*). The ICC was calculated in accordance with Wirtz and Caspar (2002), with an absolute agreement (ICC_{unjust}), 2-way mixed-effects model using IBM SPSS Statistics (Version 28.0.0.0 (190)). For the subsequent paired comparisons, we used the first coder's scoring, which is why we report single measures. The ICC shows an $ICC_{unjust} = 0.868$, which is considered good (Wirtz, 2004).

4.6.2.2. Measures of event-related noticing

The noticing accuracy score (sum of points after completion of the coding process, see Table 1) was used to assess teachers' event-related noticing. Each event had a maximum score of 3 points. These were summed over all fourteen classroom management events. The maximum score achievable was therefore 42 points. We further differentiated between noticing accuracy scores for slight (four events, maximum score: 12 points) and salient disruptions (ten events, maximum score: 30 points), as we expected the slight disruptions to require more efficient monitoring behavior. They might require more top-down processing as they do not catch PSTs' attention as easily. Previous studies did not include this distinction; hence, we compared the two measures in an exploratory fashion. To facilitate comparability with existing studies, we also report the overall number of noticed events (see Stahnke and Blömeke, 2021; van Driel et al., 2021; Schreiter et al., 2022) as an indicator of teachers' noticing. In this vein, we also report the number of time and target errors as negative indicators of noticing accuracy. The highest possible counts for events, target and time errors were each 14.

4.7. Preliminary data analysis

Using G*Power (Faul et al., 2007) we conducted an *a priori* power analysis (α error probability = 0.05 and power (1 − β error probability) = 0.95. Previous research in on-action contexts exploring the effects of training to scaffold pre-service teachers professional vision obtained large effect sizes for eye-tracking parameters (Schreiter et al., 2022). According to this, we assumed an effect size of $f = 0.40$ for the analysis of variances (ANOVA) with three groups. The calculated effect size was $N = 102$. We did, however, not recruit this "preferred" sample size due to high requirements of trained staff, time and materials of our quasi-experimental mobile eye tracking study and implications by the COVID-19 pandemic.

We calculated Kruskal-Wallis tests with the between-subjects factor "prompting" (prompt vs. no prompt vs. control group). We conducted non-parametric testing due to the small sample size in each group, as in previous eye-tracking studies (see Stahnke and Blömeke, 2021; Schreiter et al., 2022) and because the normal distribution assumption (Shapiro–Wilk test) was not met for all variables and groups. In a follow up-analysis, we calculated pair-wise comparisons via Dunn-Bonferroni *post hoc* tests. This was done to examine group differences in a more differentiated way. For RQ 2, we conducted a correlational analysis reporting Pearson correlation coefficients. N = 46 participants were included in the analyses. All measures were analysed using IBM SPSS Statistics (Version 28.0.0.0 (190)). We based all analyses on two-sided tests with an alpha level of 0.05 and report adjusted *p*-values.

In order to ensure comparability between groups, we did preliminary analyses and identified group differences with regard to semester of studies, experience in school and extracurricular contexts, self-efficacy, general pedagogical and classroom management knowledge. Preliminary analyses showed that the groups did not differ significantly with regard to their general pedagogical knowledge, $H(2) = 4.552$, $p = 0.103$. Nor did tasks capturing PSTs' classroom management knowledge show any differences, $H(2) = 1.805$, $p = 0.406$. We, thus, reanalyzed the classroom management item with an open response format dealing with planning aspects of concrete teacher behavior (König and Blömeke, 2009). Focusing only on the criterion of classroom management strategies for teaching we further looked at how often PSTs answered classroom management and specifically monitoring strategies. We found that both experimental groups name more classroom management strategies than control group participants, $H(2) = 8.714$, $p = 0.013$. *Post hoc* testing showed significant differences between CG and EG-T ($p = 0.015$) CG and EG-TP

TABLE 1 Coding scheme for event-related noticing.

Coding	Description	Example
Step (1) Identifying all fourteen events by looking at the relevant times of interest (standardized classroom management events).		
Event 1–14	The duration of the event is coded via the beginning and end of the event. This includes the teacher's reaction (if present).	e.g. Event 9 (minute 10–12): *As soon as Alex speaks up and asks a question about the assignment that has just been explained, Kim stands up. He walks through the entire classroom to the classroom door. He opens the door and closes it again shortly afterwards. He goes back to his seat. As soon as Kim opens the door and closes it, all other pupils look at Kim and interrupt their work.*
Step (2) Coding noticing accuracy in PSTs' (gaze) videos & validate decision with PSTs' retrospective commentary and/or systematic video observation by scoring each classroom management event.		
2 = event is noticed without time error	That the event was noticed presumes that the students and objects involved in the event are fixated on and a reaction to the event is evident and/or a reference to the event is found in the retrospective commentary. A reaction includes the option of fixating on and then ignoring the event at first. It might also be the case that the event is not fixated on, but noticed through peripheral vision or auditory cues. Thus, the final decision is made based on PSTs' retrospective commentary and observations. In addition, the teacher does not commit a timing error, i.e., the teacher reacts to the disruption early and no other pupil(s) gets(s) involved.	*As Kim gets up and walks to the door, the teacher notices the behavior. This happens before other pupils interrupt their work.*
1 = event is noticed with time error	Pupils and objects involved in the event are fixated on and a reaction to the event is evident and/or a reference to the event is found in the retrospective commentary. A reaction includes the option of fixating on and then ignoring the event at first. It might also be the case that the event is not fixated on, but noticed through peripheral vision or auditory cues. Thus, the final decision is made based on PSTs' retrospective commentary and observations. However, the teacher commits a timing error, i.e., the teacher reacts to the disruption too late and other pupil(s) gets(s) involved.	The definition of a timing error for each event was defined in advance, as the events and pupils' reactions to the pre-defined events were standardized. An example: *Only after the other pupils have become aware of Kim's behavior does the teacher identify the behavior.*
0 = event is not noticed	Pupils and objects involved in the event are not fixated on or no reaction to the event is evident and no reference to the event is found in the retrospective commentary. It is also possible that the event is fixated on but not cognitively processed. Thus, the final decision is made based on PSTs' retrospective commentary and observations.	*The teacher is engrossed in conversation with Alex and stands with her/his back to the class. The teacher does not identify the event, in that Kim standing up, opening and closing the door remains unattended. However, other pupils notice Kim's behavior and interrupt their work.*
Step (3) Coding whether noticing included a target error or not, i.e., identification of the wrong pupil(s) participating in the classroom management event.		
0 = target error 1 = no target error	Teachers might commit an object/ target error (Kounin, 1970) by fixating on and/or addressing the wrong pupil during the simulation or in their retrospective commentary and/or observation. If target error is observed, 1 is coded.	The definition of an object error for each event was defined in advance, as some events explicitly provoked target errors. e.g. Event 8: *As soon as the teacher writes the guiding question on the board, Robin starts a conversation with Kim. The teacher turns around, fixates only on Kim and admonishes him to please be quiet.*

($p = 0.049$). Only participants of the EG-T (36,9%) and the EG-TP (31,6%) specifically report monitoring strategies.

Self-efficacy, $H(2) = 0.388$, $p = 0.824$, and practical experiences in school $H(2) = 0.638$, $p = 0.727$, and outside of school $H(2) = 0.967$, $p = 0.617$, were not significant. The groups differed significantly with regard to their semester of studies, $H(2) = 11.324$, $p = 0.003$. Dunn-Bonferroni *post hoc* tests with adjusted p-values showed that there were no significant differences between EG-T and CG ($p = 0.598$), or

EG-T and EG-TP ($p = 0.084$). However, CG and EG ($p = 0.003$) differed significantly in that PSTs in EG-TP had been enrolled for an average of 6.00 semesters ($IQR = 1$) and in CG 7.00 semesters ($IQR = 2$).

For EG-TP, we also looked at visual intake of the prompt during and the usage of prompts before the simulation. For the former, we expected this to be an indicator of how often PSTs refocused on the task during the simulation. Preliminary analysis of the $AOI_{promptcard}$ showed differences with regard to visit count on the prompt card. One PST visited the prompt card 18 times, two ten times and another eight an average of three times during the simulation. However, the other four PSTs visited the prompt card zero times during the simulation. To investigate the usage of prompts before the simulation we explored the lesson plans handed in by the PSTs. Around two thirds (77,8%) of the EG-TP participants interacted with the cognitive prompts, in that we see notes with regard to the tasks (see Figure 4) in the lesson plan. Most of the EG-TP participants summarized effective monitoring strategies and planned strategies for one or both of the exemplary events (36,8%). 21,1% of PSTs summarized effective monitoring strategies but did not plan strategies for one or both of the exemplary events and 21,1% planned but did not summarize the strategies. The last group of PSTs (21,1%) showed no written notes of planning or summarizing monitoring strategies.

Although, the EG-T was not instructed to do so, we find that 30,0% of PSTs of EG-T noted down classroom management strategies in their lesson plan. Thus, they applied their classroom management knowledge and thought about how to use it during the simulation. This is not observed for any participant in the control group. It additionally supports the claim that both experimental groups gained knowledge about classroom management during the training.

5. Results

5.1. Global noticing (RQ 1.1)

The results in Table 2 refer to PSTs' global noticing. Out of the total number of fixations during the simulation, $AOI_{students}$ accounts for an average of around a third. Descriptive results show that fixation and visit count for the control group are lower compared to the training group and prompted group (see Table 2). However, the Kruskal-Wallis test revealed no significant differences between the three groups for either fixation or visit count (see Table 2). Nor did we find significant differences between groups for average visit and fixation duration.

As global measures, $GC_{fixationcount}$ (≥ 0.11; ≤ 0.31) and $GC_{visitcount}$ (≥ 0.07; ≤ 0.27) show that all PSTs seem to distribute their attention relatively evenly (zero expresses that all students receive the same amount of gaze). The GC tended to be lower for visit/fixation count than visit/fixation duration, which suggests that PSTs distribute how many times they look at students more equally than how long they look at each student. There were no statistically significant differences between groups in any GC measures (see Table 2).

5.2. Event-related noticing (RQ 1.2)

Table 3 shows results for all relevant measures concerning PSTs' event-related noticing. In general, none of the PSTs reached the maximum noticing accuracy score of 42 points. The medians for all three groups range around a bit more than two thirds of the achievable total score. They all show a high number of noticed events; however, high numbers of target and time errors resulted in lower noticing

TABLE 2 Results of the Kruskal-Wallis test with regard to PSTs' global noticing.

Variable	CG[a]		EG-T[b]		EG-TP[c]		Values of significance		
	Mdn	*(IQR)*	*Mdn*	*(IQR)*	*Mdn*	*(IQR)*	*H* (*df* = 2)	d	*p*
$AOI_{student}$									
Fixation count (%)	31.22	(12.01)	36.07	(9.01)	34.17	(10.28)	3.199	0.34	0.202
Visit count (%)	34.70	(5.58)	36.24	(3.98)	35.51	(1.95)	1.783	0.14	0.410
Average fixation duration (sec)	0.41	(0.14)	0.38	(0.18)	0.40	(0.18)	0.797	0.34	0.671
Average visit duration (sec)	0.89	(0.30)	0.87	(0.35)	0.88	(0.40)	0.207	0.42	0.902
Gini-coefficient (GC) $AOI_{student}$									
$GC_{fixation\ count}$	0.19	(0.08)	0.22	(0.09)	0.21	(0.05)	1.195	0.28	0.550
$GC_{visit\ count}$	0.17	(0.04)	0.16	(0.09)	0.18	(0.05)	2.807	0.28	0.246
$GC_{fixation\ duration}$	0.23	(0.06)	0.25	(0.11)	0.25	(0.06)	0.580	0.37	0.748
$GC_{visit\ duration}$	0.24	(0.07)	0.26	(0.11)	0.25	(0.09)	0.489	0.38	0.783

[a]Control group: $n = 12$.
[b]Experimental group with training: $n = 19$.
[c]Experimental group with training and prompting: $n = 15$.

accuracy scores. It is noticeable that lower noticing accuracy scores and higher numbers of time and target errors were especially common among control group participants and for slight classroom events. The trained and prompted group (EG-TP) exhibited the highest median score, the control group (CG) the lowest.

Inferential Kruskal-Wallis tests show that PSTs' total noticing accuracy scores did not differ significantly between groups. Though, we find significant differences with regard to noticing accuracy scores for all slight classroom management events. *Post hoc* tests revealed that there were significant differences between EG-T and EG-TP ($z = -3.114$, $p = 0.006$, $r = 0.46$). For the salient events, no significant differences were found (for box plots see Supplementary material). This is in line with the number of noticed classroom management events, where Kruskal-Wallis tests showed no significant differences.

We also looked at the number of target errors made by the PSTs. Here, we find a significant large effect. *Post hoc* testing revealed no significant differences between EG-TP and EG-T, but both experimental groups significantly differed from control group; EG-T and CG ($z = 3.132$, $p = 0.005$, $r = 0.57$); EG-TP and CG ($z = 3.743$, $p = 0.001$, $r = 0.72$). Similar differences were found for the number of time errors. Dunn-Bonferroni *post hoc* tests show that there were again no significant differences between EG-TP and EG-T, but between EG-T and CG ($z = 3.719$, $p = 0.001$, $r = 0.68$) and between EG-TP and CG ($z = 3.503$, $p = 0.001$, $r = 0.67$) (for box plots see Supplementary material). All significant differences have mid to strong effect sizes (Cohen, 1988), from $d = 0.83$ to $d = 1.41$ and $r = 0.46$ to $r = 72$.

5.3. Association of object- and event-related noticing measures (RQ 2)

Correlational analysis of the global and event-related measures revealed that the total noticing accuracy score and noticing accuracy score for salient events positively correlate with the percentage of fixation and visit count on $AOI_{student}$ (see Table 4). In addition, the noticing accuracy score for salient events had medium correlations with the Gini coefficients (GC) of fixation count (see Table 4). No further significant associations between the number of noticed classroom management events, target or time errors and global noticing measures were found.

6. Discussion

The aim of the present study was to empirically test whether training and prompting can promote PSTs' noticing during teaching. For this purpose, PSTs' knowledge and knowledge activation were varied experimentally over one control and two experimental groups. A standardized classroom simulation was used to control for the students, objects and events occurring in the classroom. Using eye movement measures, retrospective commentaries by PSTs and coding by trained observers, indicators of event- and global noticing were collected and compared between the three conditions.

Summing up the results with regard to RQ 1.1., training and prompting did not affect PSTs' global noticing of students. The results are not consistent with hypothesis 1.1a, in that neither intervention led to a higher percentage of visits/fixations and shorter mean fixation/visit duration on students in the classroom. Inferential statistics indicated no significant differences between the three groups in fixation/visit count or fixation/ visit duration on $AOI_{students}$. Additionally, hypothesis 1.1b was not confirmed. Trained and prompted PST did not have lower Gini coefficient values compared to the control group. No statistically significant differences between groups were found on any Gini coefficient value. The calculated Gini coefficients for mean fixation and visit count suggest that PSTs' distributed their gaze fairly evenly across the seven students in the standardized classroom simulation. Our Gini values for fixation and visit count are a bit lower than in previous studies (Cortina et al., 2015; Dessus et al., 2016; Smidekova et al., 2020) depicting novice teachers' attentional distribution. As it has been shown that classroom complexity (Huang et al., 2021b) can affect teachers' noticing, we might conclude that the lack of significant group differences on these measures was due to the limited number of students in the classroom rather than the PSTs' use of knowledge/noticing. Our standardized setting of a reduced-complexity classroom with only seven students may have elicited similar eye movements across all students.

For RQ 1.2, we conclude that training and prompting did affect PSTs' event-related noticing of classroom management events. Our results partly confirm hypothesis 1.2. Descriptive statistics show that PSTs with both training and prompting achieved higher noticing accuracy scores on the classroom management events compared to the control group. For the total score, no significant effects are observed for the experimental groups compared to the control group. Though, we find significant differences between PSTs receiving both training and prompting and those who received training only with regard to noticing accuracy of slight events. Differences in noticing accuracy scores for salient events were not found. Additionally, the number of noticed classroom management events did not differ significantly. Hence, prompting and training affected noticing accuracy of slight events but not the number of noticed classroom management events. We assume that more top-down attention improved noticing qualitatively rather than quantitatively. This is also supported by the following results. Both experimental groups made significantly fewer time and target errors compared to the control group. Training and prompting seems to have helped PSTs notice classroom management-related events more accurately, in that they selectively attended to the events at an earlier point in time and less often identified the wrong pupil. We see strong effect sizes here. Nevertheless, if we interpret these effects, we need to discuss and contextualize the specific group differences. At first glance, the differences between the experimental groups and the control group in terms of target errors do not seem to be very large, with 1 error versus 0 errors. For the count of time errors, the median is two less for the experimental groups (see Table 3). How meaningful these differences are for practice can be argued in different ways. Viewed over an entire lesson, an object or timing error may have little effect on the teacher in the short term. But if they accumulate over several lessons and we consider motivational outcomes of the students we might argue that these are of great relevance. This becomes even more important when we consider that our simulation is a complexity-reduced setting with only 20 min lesson time and seven students. It is noticeable, if more pupils become involved or if a student is wrongly reprimanded in the case of an object error, learning time is lost.

TABLE 3 Results of the Kruskal-Wallis test with regard to PSTs' event-related noticing.

Variable	CG[a]		EG-T[b]		EG-TP[c]		Values of significance			Results of post-hoc analysis		
	Mdn	*(IQR)*	*Mdn*	*(IQR)*	*Mdn*	*(IQR)*	*H* *(df = 2)*	*d*	*p*	CG vs. EG-T	CG vs. EG-TP	EG-T vs. EG-TP
Noticing accuracy score												
Total (Max. 42)	32.00	(6.00)	32.00	(7.00)	34.00	(4.50)	2.956	0.30	0.228	ns	ns	ns
Salient events (Max. 30)	25.00	(6.00)	27.00	(5.00)	26.00	(2.75)	3.261	0.34	0.196	ns	ns	ns
Slight events (Max. 12)	6.00	(4.00)	5.00	(3.00)	7.00	(1.75)	9.706	0.92	0.008**	ns	ns	-**
Number of												
Classroom management events (Max. 14)	12.00	(2.00)	11.00	(2.00)	12.00	(1.75)	2.109	0.10	0.348	ns	ns	ns
Time errors (Max. 14)	5.00	(1.00)	3.00	(1.00)	3.00	(1.75)	16.231	1.41	<0.001***	-***	-***	ns
Target errors (Max. 14)	1.00	(0.00)	0.00	(1.00)	0.00	(0.00)	15.136	1.33	<0.001***	-***	-***	ns

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ns, not significant.
[a]Control group: $n = 11$.
[b]Experimental group with training: $n = 19$.
[c]Experimental group with training and prompting: $n = 17$.

TABLE 4 Results of correlational analysis between event-related and global noticing measures.[a]

Variable	$GC_{students}$				Fixation measures $AOI_{students}$		Visit measures $AOI_{students}$	
	Fixation count	Fixation duration	Visit count	Visit duration	Count	Average duration	Count	Average duration
Noticing accuracy score								
Total	0.212	0.109	0.149	0.139	0.323*	0.013	0.373*	0.084
Slight events	−0.079	−0.107	−0.085	−0.102	−0.114	−0.106	0.043	−0.162
Salient events	0.328*	0.220	0.254	0.254	0.504**	0.098	0.496**	0.231
Number of								
Classroom management events	0.221	0.116	0.156	0.139	0.196	0.021	0.265	0.054
Target errors	0.120	0.187	0.141	0.148	−0.170	0.181	−0.116	0.119
Time errors	−0.121	−0.227	−0.102	−0.240	−0.178	−0.072	−0.108	−0.086

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a]Pearson correlation coefficient.

From our results it is more difficult to confirm hypothesis 1.2 with regard to the differences between the two experimental groups. Whether only prompting affects PSTs remains unclear. Some of our results indicate that specifically the prompted group differed compared to the control group. We can cautiously conclude that prompting might have additionally helped to activate knowledge and might have contributed to more effective (or at least not less effective) event-related noticing especially for slight events. However, due to the different numbers of visits to the $AOI_{promptcard}$ during the simulation, we should be cautious with such conclusions. Additionally, our study had a more demanding, complex setting compared to studies exploring instructional effects during video observation (Schreiter et al., 2022; Grub et al., 2022b). During TeachEyeClass, PSTs are not able to concentrate solely on the task of observing classroom events and students, but must simultaneously teach and react to students' behavior. Accordingly, the influence of minimal instructions (in our case the cognitive prompt before the simulation) is an interesting question for future research. A future study might include one experimental group receiving only prompting, similar to Schreiter et al. (2022). In addition, we can investigate certain time spans in the simulation. The effect of cognitive prompting might fade over time. Further investigation might also include the different visual intake of the $AOI_{promptcard}$ as a possible influencing factor. This might be useful to explain the missing differences between the two experimental groups.

Finally, in RQ 2, we asked whether event-related noticing is associated with global noticing measures. Evaluating hypothesis 2, only one expected positive correlation between the fixation and visit count and noticing accuracy was found. PSTs with higher total noticing scores also had a higher percentage of fixations and visits on $AOI_{student}$. Exploratory comparisons also showed this for salient events. In addition, PSTs with higher accuracy scores for salient events also exhibited higher Gini values for fixation count. Thus, they distributed their attention less equally across students. This result seems especially important, when looking into the contextual nature of noticing, i.e., differences in noticing between events with varying levels of saliency. Although we cannot tell about a causal relationship here, our results indicate that noticing salient events is associated with global measures of attention. This might be due to the fact that salient events (students engaging in disruptive behavior) might catch teachers attention more and/or lead teachers to use their gaze to intervene or follow students behavior. We thus see increased percentage of fixation count, if teachers notice salient events more accurately. Further significant association with regard to the slight events were not found. Thus, we did not find support for the assumed associations between event-related and global noticing measures in the expected directions. In connection with theoretical considerations, it would be fruitful to discuss to what extent global noticing is part of the construct of teacher noticing. If we draw back on the different operationalizations of teachers noticing introduced in chapter 2.2, global noticing measures often show aggregated eye movements over an entire instructional period. It disregards specific students' behavior and may perhaps be less informative than event-related noticing measures. The influence of knowledge and possibly also experience onto global noticing during teaching, may be particularly dependant on individual classrooms and contexts (e.g., student behavior).

Based on the discussion of our results, we generally conclude that the selection of suitable eye movement measures is of central importance. This can be stated based on our study's results, but is also underlined by the heterogeneous findings in the field of teachers' noticing assessed by eye movements. In our quasi-experimental study, we find no significant effects with regard to measures of global noticing. In contrast to previous on-action studies using prompting and training (Schreiter et al., 2022), we do not find more efficient visual information processing with regard to the task-relevant area of students in the form of higher fixation/visit counts and average fixation/visit durations in the two experimental groups.

Positive effects of the classroom management training on event-related noticing were found. PSTs did not identify more relevant classroom managements events, but achieved a higher noticing accuracy. This is in line with previous in-action studies in which a similar number of noticed classroom management events were found between different expertise groups and partially in line with Grub et al.s' (2022a) on-action study. The latter showed that higher knowledge leads to classroom disruptions being identified more often and more quickly. As the experimental groups had a significantly lower count of time errors, we demonstrate an earlier event detection in both experimental groups in our study (who can be expected to have more knowledge compared to the control group). As Stahnke and Blömeke (2021) only found expertise differences with regard to the number of noticed events during video observation of partner work scenes, analysing event-related noticing measures separately for student-led vs. teacher-led activities during the simulation might be a promising next step.

The relevance of eye movement parameter selection is being emphasized by Smidekova et al. (2020) for expert-novice comparisons. Our results support this notion. They raise the question of whether the mere consideration of eye movement measures on objects in the classroom is less useful in intervention studies with inexperienced teachers (with very similar levels of teaching experience). The global eye movement measures used in this study might not be good indicators to exclusively examine when exploring instructional effects of PSTs' training and learning in teacher education. It would hence be fruitful to for future data analysis to include other eye movement measures, i.e., scanpaths (Kosel et al., 2021; Huang et al., 2021a) and event-related areas of interest (Stahnke and Blömeke, 2021; Grub et al., 2022b). It would also be interesting to bring more experienced teachers into the TeachEye-ClasS environment to test for expertise differences in global noticing like those found in previous studies in real classrooms (Cortina et al., 2015; Huang et al., 2021a). We might assume that classroom management scripts established through repeated exposure to events and teaching experiences (Wolff et al., 2021) particularly affect perception and thus global noticing. Accordingly, higher fixation counts and shorter fixation durations on students might be seen only among experts.

There also seems to be little indication that the Gini coefficient should be used as a marker of effective noticing. We could not substantiate the expected directional correlations and in contrast to event-related noticing, training and prompting did not significantly affect the attention distribution onto students. Smidekova et al. (2020, p. 13) previously raised a concern that the Gini coefficient has been an inconsistent indicator of expertise. We assume that the (un)evenness of the distribution of attention greatly depends on the complexity of the classroom context (e.g., relevant events, number of students). In our study, a more uneven distribution of attention goes hand in hand with a higher noticing accuracy for salient events. (Over-)focusing on relevant students might thus be helpful for noticing relevant events or attending to them more accurately (earlier and in connection with the right person). In this line, one might discuss the limited relevance of an equal attention distribution for theoretical conceptualizations of noticing as part of teachers' professional competence (Blömeke et al., 2015) and an indicator of teaching quality.

The different findings by type of event (salient vs. slight) allow us to draw further conclusions. It seems to be important to distinguish between events with different levels of salience when studying teachers' noticing. Our results indicate that prompting and training did not affect noticing of salient events. As already noted in previous on-action studies (Grub et al., 2022b, p. 13), salient events (e.g., a student throwing a paper ball across the room) might trigger more bottom-up attention; hence, the effects of activating knowledge as a top-down driver might be minimal here. Our results support this assumption in an in-action context. Noticing salient events might require less knowledge about classroom management, which increases with experience (Stahnke and Blömeke, 2021; Grub et al., 2022b). Whether this difference is also evident with regard to PSTs' reactions to these events remains unclear at this point. Novice and expert teachers are argued to differ profoundly not only in their perception and interpretation but also in their responses to classroom management-related events (Wolff et al., 2021). In a future study, it might be promising to examine how teachers react to salient and slight events. In this line, there is potential to explore a possible direct connection between noticing and teaching quality with our data. For this, established measures such as the CLASS rating (Pianta et al., 2012) could be used.

6.1. Strengths, limitations, and significance for future research

Our study examined differences in PSTs' noticing in-action between two experimental groups that were both attending a training, one of which received additional cognitive prompting, and one control group. The results suggest a positive influence of our training, which aimed to impart classroom management knowledge, on event-related noticing accuracy during teaching.

Our study includes several individual strengths that should be emphasized. To our knowledge, there are few studies using mobile eye tracking, thus, providing such insight into effects on teachers' noticing in-action. The quasi-experimental design, direct training of knowledge offered to investigate group differences and the relevance of knowledge as a top down driver, separately from teaching experience. The standardized teaching simulation ensured comparability between the groups of PSTs and made it possible to obtain insights into event-related noticing during teaching. We used several sources of information to assess teachers' noticing and present a novel approach that links verbal data with eye-tracking records captured in teachers' gaze videos to assess PSTs' event detection by means of trained observers. In addition, our sample focused on PSTs to obtain concrete possibilities and ideas for teacher education. Previous studies looking into noticing during teaching have so far mainly involved expertise comparisons.

Being able to notice classroom management-related events (van Es and Sherin, 2021) is regarded as a crucial and challenging skill for beginning and expert teachers alongside actually managing a classroom effectively. Based on our results, we conclude that we were able to improve PSTs' event-related noticing accuracy and influence knowledge as a top down driver of noticing. The further development of teaching-learning environments such as our seminar and the simulation environment are thus of particular importance. Our standardized teaching simulation can be used for assessment and practice of PSTs' noticing skill in teacher education.

Of particular relevance are our null findings regarding fixation/visit count and average duration on students. We acknowledge that experience and specific knowledge parts might influence global noticing in different ways, which should be examined separately in future expertise studies. This result is also of particular interest when it comes to the added value of eye-tracking technology and teacher gaze videos. Analysis of mobile eye-tracking data is time-consuming, and eye movements alone might not be as revealing in an in-action context. Our coding process for PSTs' event-related noticing offers an alternative way of assessing teachers' event-related noticing in a standardized learning environment.

Our study has strengths, but the results must also be interpreted in light of several limitations.

First, we examined effects on PSTs' noticing of the pre-defined classroom management events. Thus, the results cannot be transferred to other (e.g., more complex and less salient) events in the classroom or associated with other instructional quality characteristics. Current on-action studies also focus on classroom management. Future research should include more observation foci in in-action settings.

Secondly, we looked at selected eye-tracking measures (i.e., fixation/visit count, average fixation/visit duration) and areas of interests. The eye movements were examined with respect to the global area of interest of all students in order to establish links to previously found expertise differences in in-action studies. We did also not include classroom events as event-related areas of interests. As our trained observers' coding revealed qualitative differences, (other) eye movement measures onto event-related areas of interest (see Stahnke and Blömeke, 2021) might reveal different results. This might include the time to first fixation or the gaze relational index (see Grub et al., 2022b).

Thirdly, we find no significant differences with regard to PSTs' classroom management and general pedagogical knowledge as assessed by the PUW test (König and Blömeke, 2010) between experimental groups and control. We assessed PSTs' knowledge after the training and before the simulation. In this way, we hoped to detect classroom management knowledge differences between the control group and experimental groups. However, the students did not differ significantly in the overall number of points they achieved in the test. Nor did they differ in the dimension of classroom management knowledge. We, though, do not attribute this to a lack of knowledge increase, but rather a misfit between the type and number of test items and the specific knowledge imparted in the seminars. Our results show strong effects on noticing classroom management events. In addition the three classroom management items used in the test also focus on planning aspects of concrete teacher behavior and the use of rules and routines during instruction. As the second part of the course on classroom management together with the prompts distinctively focused behavioral strategies during instruction (e.g., monitoring, group activation), it is therefore reasonable to assume that the used test items may not have captured the specific knowledge facets that contribute to PSTs' noticing of classroom management events. Because of this we analyzed one of the open response items in more detail. We also looked at PSTs' handed in lessons plans. There we found significant differences with regard to the experimental groups and control. Both experimental group more frequently noted down classroom management strategies in the test item and their lesson plan. It supports the claim that both experimental groups gained knowledge about classroom management during the training. In subsequent studies, we plan to use self-developed instruments to capture specific classroom management knowledge, and pre-post measurement will be carried out for the experimental groups. In this way, it will be possible to trace developments in classroom management knowledge over the course of the seminar.

Fourth, due to COVID-19 restrictions and for economic reasons, think-aloud protocols were conducted online and thus not under standardized conditions. Also the stimulated recall of the simulation occurred not directly after TeachEyeClasS and the collection of the eye-tracking data and we had a notably longer delay for the control group. All this may have influenced PSTs' retrospective commenting and, respectively, coding of PSTs' noticing performance. For this reason, we did not use the PSTs' retrospective reports alone, but had trained coders assess event-related noticing based on PSTs' videos and reports. Both sources of information were used to objectively evaluate event-related noticing. Solely assessing subjective reports by PSTs might elicit different results. To further rule out the influences of delay, we asked observers during the scoring procedure, to note down and comment for each event, whether PSTs' video or think aloud commentary indicated different noticing score than the think aloud commentary. There were in general few events, where this was the case ($N = 10$). In addition, those instances were not significantly more common for control group participants. In future studies, it seems promising to examine to what extent retrospective think-aloud protocols alone or in combination with other methods (e.g., hand signaling by van Driel et al., 2021) can provide valid measurement and comparable results.

Fifth, our study uses a simulated classroom environment. Although the simulated and highly standardized classroom environment forms a strength of our study, we must note the limitation of transferability to real or more diverse classroom settings. This limitation draws upon several design choices we made to reduce cognitive load during the simulation for our PSTs. The class size of seven pupils, familiarity with the learning group and also the standardized events. These aspects might impact teachers noticing (for classroom events see Huang et al., 2021b) and teachers' stress (for class size see Huang et al., 2022). To mimic real classroom practice we situated the simulation within a field practicum and gave the PSTs a written description of the learning group. In a previous study we also found good results with regard to PSTs reported authenticity and task load of the simulation (see Telgmann and Müller, in preparation). Thus, we conclude that the standardized classroom simulation and the tasks PSTs face during the simulation approximate real classroom practice and can in some degree be transferred to real classroom practice. In this line, it would be interesting to follow up on the PSTs during their real field practicum to assess their noticing skills during regular classroom teaching.

Finally, our study had a small sample size, which particularly limits the broader implications that can be drawn from the findings. We did not reach the "preferred" sample size of our *a priori* power analysis. Although, for event-related noticing we find significant large effects similar to previous studies (Schreiter et al., 2022). Future research should work with larger samples. This might also be promising as we are then able to conduct further investigation of different PST groups in our sample. Statistical control of the PSTs' degree (special education vs. secondary education) was not possible due to the small sample size. We randomly divided all PSTs to the groups, though, the study program might influence noticing indirectly. Certain attitudes and expectations of students behavior that are worth attending might be an influencing factor.

7. Conclusion

The aim of the present study was to gain further insight into the effects of a classroom management training and prompting on PSTs' event- and global noticing. By examining the direct training of knowledge in a quasi-experimental study our results suggest that prompting noticing during teaching is possible. We were not able to find differences in global noticing between our two experimental groups and control group. However, we showed that prompting and training can affect PSTs' event-related noticing in that more knowledge might have helped PSTs to notice classroom management events earlier and more accurately. Our study represents only a first step toward understanding the influence of knowledge and the relevance of interventions for PSTs' noticing. Further studies in this field are needed to clarify how to design interventions to help PSTs be aware of classroom events. This research specifically emphasizes the potential of (standardized) reduced-complexity classroom simulations for practicing and assessing the skill of noticing. In addition, we advocate a targeted use of suitable measures to explore PSTs' noticing in teacher education.

Data availability statement

The datasets presented in this article are not readily available because of legal and privacy restrictions. The minimal data set supporting the conclusions of this article will be made available by the authors upon request, without undue reservation. Requests to access the datasets should be directed to LT, leonie.telgmann@iew.uni-hannover.de.

Ethics statement

Ethical approval was not required for the studies involving humans because consents for data collection were obtained from individuals on the legal basis for the collection and processing of personal data in accordance with the General Data Protection Regulation (GDPR) and German national data protection laws and regulations. The data protection officer of Leibniz University Hannover reviewed the consent forms as part of the data collection for this study. 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

LT: Conceptualization, Formal Analysis, Investigation, Methodology, Project administration, Writing – original draft. KM: Conceptualization, 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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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1266800/full#supplementary-material

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Guiding pre-service teachers' visual attention through instructional settings: an eye-tracking study

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In complex classroom situations, pre-service teachers often struggle to identify relevant information. Consequently, classroom videos are widely used to support pre-service teachers' professional vision. However, pre-service teachers need instructional guidance to attend to relevant information in classroom videos. Previous studies identified a specific task instruction and prompts as promising instructions to enhance pre-service teachers' professional vision. This mixed-methods eye-tracking study aimed to compare pre-service teachers' visual attention to information relevant for classroom management in one of three instructional conditions. Participants viewed two classroom videos and clicked a button whenever they identified situations relevant to classroom management in the videos. They got either (1) a specific task instruction before video viewing ($n = 45$), (2) attention-guiding prompts during video viewing ($n = 45$), or (3) a general task instruction ($n = 45$) before video viewing as a control group. We expected a specific task instruction and prompts to better guide participants' visual attention compared to a general task instruction before video viewing because both experimental conditions contained informational cues to focus on specific dimensions of classroom management. As both a specific task and prompts were assumed to activate cognitive schemata, resulting in knowledge-based processing of visual information, we expected the specific task instruction to have a similar attention-guiding effect as prompts during video viewing. Measurements were conducted on an outcome level (mouse clicks) and on a process level (eye tracking). Findings confirmed our hypotheses on an outcome level and in part on a process level regarding participants' gaze relational index. Nevertheless, in a disruptive classroom situation, participants of the prompting condition showed better attentional performance than participants of the other conditions regarding a higher number of fixation and a shorter time to first fixation on disruptive students. Further qualitative analyses revealed that, when observing classroom videos without instructional guidance, pre-service teachers were less likely to identify disruptive situations in the video and more likely to attend to other situations of classroom management concerning the teachers' action. We discuss advantages of both attention-guiding instructions for pre-service teacher education in terms of the economy of implementation and the salience of situations.

KEYWORDS

professional vision, instructional settings, eye tracking, mixed methods, preservice teacher education, prompting, specific task instruction

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1. Introduction

For the past few years, educational research increased attention on teachers' professional vision (Goodwin, 1994; Seidel and Stürmer, 2014; van Es and Sherin, 2021; König et al., 2022). Based on a definition of Seidel and Stürmer (2014), teachers notice relevant information in the classroom and reason its consequences on further actions. An important context is classroom management: effective classroom management requires professional vision to establish and maintain a beneficial learning atmosphere (Gold et al., 2017). For instance, noticing disruptive student behavior at an early stage is an important aspect of successful classroom management (Grub et al., 2020; Gold et al., 2021).

However, professional vision differs systematically between pre-and in-service teachers (Gegenfurtner et al., 2011; Wyss et al., 2021). For pre-service teachers, it is challenging to make quick decisions about what information to pay attention to and what to ignore during lessons as well as how to make sense of students' behavior, positioning, and participation (Santagata et al., 2021). As a result, we speak about visual expertise when experienced teachers are able to notice situations quickly and interpret them based on solid knowledge in order to consider their options for further action. In a following section, the characteristics of visual expertise qualities will be addressed in more detail. Consequently, it is necessary to establish learning environments for pre-service teachers to develop visual expertise. Here, video formats turn out to be effective tools (Gaudin and Chaliès, 2015). They are widely used in teacher trainings (Kersting, 2008; Zottmann et al., 2012), as they represent simultaneity and multidimensionality of the classroom (van Es and Sherin, 2002; Sherin and van Es, 2005).

However, video analysis requires high mental effort for pre-service teachers to identify relevant situations (Blomberg et al., 2013; Mayer and Fiorella, 2014; Martin et al., 2022). For this reason, it is important to provide instructional support that guides their visual attention during video viewing (Star and Strickland, 2008; Seidel et al., 2013; Gaudin and Chaliès, 2015). Two promising opportunities for instructional support are specific tasks that are provided before video viewing and attention-guiding prompts that are provided during video viewing (Demetriadis et al., 2008; Walker, 2008; Grub et al., 2022a,b; Gabel and Gegenfurtner, 2023; Martin et al., 2023). In this study, we investigated the attention-guiding effect of these instructions. To measure attentional processes, we used eye-tracking technology as an established method to analyze participants' eye movements (Wolff et al., 2016; McIntyre et al., 2017; Seidel et al., 2021; Stahnke and Blömeke, 2021; Keskin et al., in press).

2. Theory

2.1. The salience of classroom management situations

An important context where teachers require professional vision is classroom management. To provide an effective learning atmosphere, they need to monitor and coordinate all events occurring in the classroom (Kounin, 1970; Evertson and Weinstein, 2006; Bear, 2015). However, it is often difficult for pre-service teachers to distinguish relevant from irrelevant situations, as various events occur at the same time and require increased attention (van Es and Sherin, 2002; Sherin and van Es, 2005; Blomberg et al., 2013). In addition, pre-service teachers also seem to struggle noticing all critical events of all students in the classroom which leads them to reduce their attention to fewer students (Kosel et al., 2021). For this reason, the salience of the situations plays a crucial role in professional vision. Salient situations have a higher visibility. Large movements such as a student getting up from his seat, for example, can be a salient event in the classroom, whereas a student playing with his pencil might be less salient. These situations are frequently regarded as relevant since they catch more attention. However, salient situations are not always relevant situations. The question which classroom management situations are more or less salient to pre-service teachers remains open and will be investigated in this study. To guide pre-service teachers' attention toward situations that are important – but not always salient – instructional support is needed. For this reason, the first aim of this study is to compare what kind of instructional support is needed to guide their attention toward important classroom management situations. In addition, we aim to examine which classroom management situations pre-service teachers consider as more and less salient. Identifying which relevant situations they perceive as less salient, let us conclude which situations they are more likely to need instructional support for.

2.2. The cognitive theory of visual expertise

As pre-service teachers have little practical experience and little professional knowledge, their professional vision differs from experienced in-service teachers. This is why we talk about visual expertise in this section. To understand which processes pre-service teachers need to acquire, we take a closer look at the cognitive theory of visual expertise (Gegenfurtner et al., 2023). The theory shows the characteristics of experienced teachers' professional vision and is based on three assumptions: (1) Experts can process a large amount of information in their long-term working memory due to their extended capacity. (2) Second, due to their previously stored knowledge, they also process information in a knowledge-driven manner. (3) Finally, through reflective visual practices, experts actively shape visual information in their environment and develop extended cognitive schemata. Based on these three presumptions, there are cognitive processes that determine visual expertise: firstly, experts process visual information foveally (information are visually focused) and parafoveally (information from the visual field's periphery) in their visual register, highlighting a holistic perception of visual information. After selecting important and ignoring irrelevant visual information, these are aggregated in image chunks. Those image chunks are further enriched with previously stored declarative knowledge in long-term working memory, developing an integrated mental model of the perceived visual information. By interacting with the environment, expert teachers enrich this model with further visual information. Finally, experts use metacognitive strategies and knowledge in order to regulate and monitor the visual processes.

In contrast, pre-service teachers typically do not have these cognitive processes fully developed yet: they mainly process information foveally – that is, they only process information they visually focused on (Gegenfurtner et al., 2023). What happens around their visual focus is often not perceived. Furthermore, they tend to struggle with structuring and integrating their knowledge – which is usually also restricted – to their visual information (Wolff et al., 2021). Visual expertise of teachers is an important ingredient of teacher professional vision. Like in other professions, such as medicine, sports, or transportation domains, also teachers can develop their expertise in processing domain-specific visual stimuli, which, then, gives rise to their very highly developed professional vision in classrooms. To make professional vision and its differences between pre-and in-service teachers measurable, eye-tracking technology has become an important methodological approach (Holmqvist et al., 2011).

2.3. Eye tracking as methodological approach to investigate professional vision

So-called areas of interests (AOIs) are characterized to analyze eye movements of a certain area. Various eye-tracking parameters can be conducted to measure gaze movements regarding these AOIs: (a) number of fixations and visits, (b) fixation durations, (c) time to first fixation and (d) the gaze relational index, which we will go into more detail now.

2.3.1. Fixation counts and visits

According to Holmqvist et al. (2011), fixations are time intervals where gaze activity has very little to no movement. Fixation visits demonstrate how frequently all fixations occur in a defined area of interest (Keskin et al., in press). While watching classroom videos, previous studies frequently compared professional vision of pre-and in-service teachers (Keskin et al., in press). In-service teachers fixate relevant situation more often than pre-service teachers (Wyss et al., 2021). According to the information-reduction hypothesis (Haider and Frensch, 1996), increasing experience might help to better distinguish task-relevant from task-irrelevant information (for a meta-analysis, see Gegenfurtner et al., 2011).

2.3.2. Fixation duration

This parameter defines how long a fixation continues (Holmqvist et al., 2011). Findings show that in-service teachers generally have a shorter fixation duration than pre-service teachers (Gegenfurtner et al., 2011). This confirms the assumption of a top-down perception of in-service teachers, since they observe teaching events through shorter fixations and thereby search for critical events in a more knowledge-driven manner (Wolff et al., 2021; Gegenfurtner et al., 2023). This contrasts the rather longer fixation durations of pre-service teachers, which seems to be caused by a stimulus-based bottom-up perception (Hershler and Hochstein, 2009; Gegenfurtner et al., 2023). These findings indicate a more holistic monitoring behavior of in-service teachers.

2.3.3. Time to first fixation

In addition, teachers should be able to recognize critical events as soon as possible to intervene quickly (Gold et al., 2021). Here, the time to first fixation can be a suitable parameter to measure this aspect of visual expertise. Grub et al. (2022b) examined whether expertise is associated with faster time to first fixation for critical events. However, no difference between in-and pre-service teachers has been found on this parameter so far (Grub et al., 2022b).

2.3.4. Gaze relational index

Finally, the gaze relational index (GRI) – the ratio of mean fixation duration and mean fixation number – is a novel metric to get insights into the depth of visual processing (Gegenfurtner et al., 2020). This parameter assumes that in-service teachers tend to have more and shorter fixations because they perceive visual stimuli selectively and in knowledge-driven manner (Gruber et al., 2010; Sheridan and Reingold, 2017). For this reason, a lower GRI indicates a more knowledge-driven, top-down perception (Gegenfurtner et al., 2020).

This methodological approach reveals different gaze parameters of pre-and in-service teachers. It is evident that visual expertise is characterized by shorter but more frequent fixations and revisits, which is an indication of improved monitoring behavior. In order to guide pre-service teachers' professional vision to relevant information in a video, knowledge-based processing is necessary (Sherin and van Es, 2009; Grub et al., 2022a; Gegenfurtner et al., 2023). However, since they have not automated a knowledge-based processing yet, instructional support is necessary to direct their attention. Pre-service teacher training should focus on the integration of knowledge into their professional vision, as knowledge helps to select relevant visual information and to ignore irrelevant visual information (Blomberg et al., 2013; Grub et al., 2022a). To support pre-service teachers developing this expertise, they need to shift their visual perception from a stimulus-driven process to a knowledge-driven process. To guide this knowledge-driven process, instructional settings can be provided.

2.4. Instructional settings to develop visual expertise

Instructional settings help learners structure their observations and integrate knowledge (Kali et al., 2003; Linn et al., 2003). By providing support, learners actively process information and focus on specific aspects in video viewing (Santagata and Angelici, 2010; Santagata and Guarino, 2011; Chernikova et al., 2023). However, instructional support can be provided at different times – prior or during video viewing. Therefore, the question arises when to guide pre-service teachers' professional vision?

For instance, general and specific tasks are instructional settings provided at the beginning of a task. In contrast to general task settings, specific task settings provide more detailed information about what should be focused on during task processing, for example to focus on smoothness and momentum in the teaching process. Through this type of instruction, specific knowledge schemata can be activated at the beginning of a task (Grub et al., 2022a). Two studies of Grub et al. (2022a,b) investigated the difference between a specific task instruction and a general task instruction to enhance professional vision in the context of classroom management. Professional vision was measured by the total number of correctly detected classroom events and their velocity of the recognition. Based on the assumption that specific task instructions can activate cognitive schemata, they expected the participants to show a faster and more accurate visual perception in the specific task setting (Grub et al., 2022a). As the cognitive theory of visual expertise outlines, a profound knowledge base directs visual perception in a top-down process (Gegenfurtner et al., 2023). In both studies, all participants ($n = 86$ in the first study; $n = 71$ in the second study) saw six video sequences and received a general task instruction for the first three video sequences, and a specific task instruction for the last three video sequences. In the specific task, the participants were asked to stop the video when they identified teaching disruptions, whereas the general task only asked them to stop the video when they identify something relevant. For both studies, no significant effect between these two minimal interventions could be found enhancing professional vision. However, the second study included eye-tracking data, which showed an attention-leading effect of the specific task instruction. When provided specific task instruction, the participants showed a more global monitoring behavior – indicated by more and shorter fixations – as well as a more focused visual perception – indicated by a higher number of fixations and a higher visit count on relevant events. Furthermore, the gaze relational index was lower with a specific task instruction than with a general task instruction indicating a scanning gaze behavior with many quick fixations. Thus, their gaze behavior – following to a specific task instruction – showed characteristics of visual expertise.

Another study examined whether a brief pre-training before video analysis can activate knowledge (Martin et al., 2023). In a single-session format, one experimental condition ($n = 29$) received a text activating subject-specific knowledge and another experimental condition ($n = 29$) received a text activating pedagogical-psychological knowledge, while the control condition ($n = 27$) received a text with general information about classroom video analysis. In the subsequent video analysis, students from the experimental conditions showed better performance regarding in professional vision than students from the control condition. Professional vision was measured by the amount and quality of references to pedagogical concepts in their video analysis. This indicates a beneficial effect of knowledge activation by providing specific content-related information before video analysis (Martin et al., 2023).

Since some prior studies imply that instructional settings at the beginning of a task may have an attention-guiding effect on visual perception, another instructional method is to provide instruction during task processing. This kind of instruction is often realized with prompting. This is an already established and tested strategy to enhance learning in various learning environments (Demetriadis et al., 2008; Walker, 2008; Kramarski and Friedman, 2014). Learners may know how to perform certain skills declaratively, but they do not apply them spontaneously in specific situations. Here, prompts serve as instructional cues that support learners to perform these skills (Berthold et al., 2007; Bannert, 2009; Bannert et al., 2015). Thus, they "do not teach new information, but rather support learners in the execution of their self-regulation knowledge and skills" (Müller and Seufert, 2018; p. 3). Regarding professional vision, cognitive prompts might help focus attention on relevant aspects during classroom video viewing (Roth McDuffie et al., 2014).

As noted in the study of Grub et al. (2022b), a specific task prior to video viewing is attention-guiding. Taking this further, it is interesting to investigate how specific task instructions perform in comparison to scaffolds that are not presented before the task, but during it. In a previous study, we compared the effect of specific task instruction and prompts on pre-service teachers noticing (Gabel and Gegenfurtner, 2023). Similarly to Grub et al. (2022a,b), participants were tasked to click a button when they identified relevant situations. They received information to focus on three specific aspects of classroom management that were either shown as a specific task before video viewing ($n = 42$) or as prompts during video viewing ($n = 43$). The findings indicated that both instructions had a similar attention-guiding effect on teacher noticing (Gabel and Gegenfurtner, 2023).

These findings provided interesting insights; however, no detailed differences can be explained. For this reason, this study examined how the types of instructions differ not only on an outcome level, but also on a process level. To measure noticing on an outcome level, we determined the events participants noticed as being relevant to classroom management. To measure noticing on a process level, eye-tracking technology can enrich this research approach. If it is true that specific task instructions have a similar effect on noticing as prompts on an outcome level, then we can assume both instructions having a similar attention-guiding effect on a process level.

3. The present study

The present study had three aims and focused on pre-service teachers' professional vision in the context of classroom management. One aim was to replicate and extend previous findings:

> RQ1: Do a specific task instruction and prompts have a similar attention-guiding effect on pre-service teachers' noticing on an outcome level – both compared to a control condition with a general task instruction?

If it is true that schema activation through prompts and specific task instructions can direct visual attention to information relevant for classroom management, then we would expect pre-service teachers to identify a similar number of relevant situations in the prompting and specific task instruction conditions (Hypothesis 1a) and a higher number in both these schema-activating conditions compared to the general task instruction condition (Hypothesis 1b).

For the second research question, we wanted to investigate the effects not only on an outcome level, but also on a process level.

> RQ2: Do specific task instructions and prompts have a similar attention-guiding effect on pre-service teachers' noticing on a process level – both compared to a control condition with a general task instruction?

Collecting data through eye-tracking technology can afford a deepened understanding of the attention-guiding mechanisms of different task instructions on a process level. Therefore, we chose two different classroom management situations and tested a set of hypotheses. In the first situation, we were interested in the gaze behavior for a critical situation where several students are disrupting the teaching process. As classroom management benefits from a quick and frequent fixation on these students, we set the areas of interest to the disruptive students and selected the eye movement parameters *time to first fixation* and *number of fixations*. If it is true that schema activation through prompts and specific task instructions can direct visual attention to information relevant for classroom management, then we would expect pre-service teachers of the prompting and specific task instruction conditions to have a similar number of fixations (Hypothesis 2a) and a similar time to first fixation (Hypothesis 2b). Compared to the general task instruction condition, we would expect both experimental conditions to have a higher number of fixations (Hypothesis 2c) and a faster time to first fixation (Hypothesis 2d).

In the second situation, we were interested in the gaze behavior during a peer learning phase where the teacher is monitoring the students' learning. Here, successful classroom management benefits from a global monitoring over the situation, which is why we set the AOIs for students, teacher, and material and chose the eye movement parameters *number and duration of fixations* and the *gaze relational index*. If it is true that schema activation through prompts and specific task instructions can direct visual attention to information relevant for classroom management, then we would expect pre-service teachers in the prompting and specific task instruction conditions to have a similar number of fixations (Hypothesis 2e), similar fixation durations (Hypothesis 2f), a similar gaze relational index (Hypothesis 2g). Compared to the general task instruction condition, we expect both experimental conditions to have a higher number of fixations (Hypothesis 2h), lower fixation durations (Hypothesis 2i), and a lower gaze relational index (Hypothesis 2j).

For the third research question of this study, Grub et al. (2022b) encouraged further studies to examine the salience of perceived situations. In the context of classroom management, we do not know yet which situations pre-service teachers are more likely to focus on. Thus, we aim to explore this qualitatively:

> RQ3: Which classroom management situations do pre-service teachers notice more likely?

Here, we aimed to identify initial trends by qualitatively examining interview data and classifying them inductively and deductively with the hope of achieving a better understanding which classroom management scenarios are more and less salient for pre-service teachers.

4. Methods

4.1. Participants

We conducted this study with a sample of $n = 135$ pre-service teachers (108 women, 27 men; $M_{age} = 20.8$ years, $SD_{age} = 2.6$) enrolled in a national teacher education program of a large German university. A majority of the pre-service teachers were in their first semester (65.7%; $M_{Semester} = 2.1$; $SD = 1.7$). Most of the participants (66.4%) had held five or less lessons as a teacher during school internships. All students participated voluntarily and were recruited in seminars or via courses to receive course credit for participation. Data collection was guaranteed to be anonymous.

4.2. Study design

This investigation followed an experimental mixed-method design. The participants were randomly assigned to one of three conditions. Experimental condition 1 provided prompts during video viewing ($n = 45$), experimental condition 2 provided specific task instruction before video viewing ($n = 45$), and condition 3 served as a control condition, providing general task instruction before video viewing ($n = 45$). We collected mouse clicks, eye-tracking parameters, questionnaire data, and interview data.

4.3. Instruments

4.3.1. Task instructions

The task for the prompting condition was: "Please click if you identify positive elements of classroom management and those that need improvements in this video." The participants saw this general instruction prior to the video and received three prompts during the video that specified important dimensions of classroom management: "Pay attention to the smoothness and momentum" (Prompt 1), "Pay attention to the handling with disruptive behavior" (Prompt 2), and "Pay attention to the omnipresence of the teacher" (Prompt 3). We decided to show event-based prompts to prime the participants' attention prior to a specific situation in the video. Each prompt lasted for 15 s and disappeared before the situation in the video occurred.

The instruction for the specific task condition was: "Please click if you identify positive elements of classroom management and those that need improvements in this video. Pay attention to the smoothness and momentum, to the handling with disruptive behavior and to the omnipresence of the teacher." The participants had 45 s to read the task instruction.

The instruction for the control condition was: "Please click if you identify positive elements of classroom management and those that need improvements in this video" without any specifications about the dimensions of classroom management. Participants had 45 s to read the task instruction.

4.3.1.1. Videos

We chose two videos from different subjects in order to minimize a subject-specific effects on pre-service teachers' professional vision. The first video was a staged video (from the video portal Toolbox Lehrerbildung) showing a mathematics lesson in 10th grade (04:30 min). The second video (from the video portal LeHet) was an authentic video showing a German as a second language lesson in 7th/8th grade (04:48 min). Both videos were comparable in length.

4.3.1.2. Questionnaire

As a control variable, we used the pedagogical-psychological knowledge test (König and Blömeke, 2010) which contains five dimensions of teaching quality (management with heterogeneity, structuring, classroom management, motivation, performance assessment) with a total of 10 closed and 8 open items.

During video viewing, we used a 7-point Likert item of Paas (1992) to measure the participants' mental effort. After each video, they rated their mental effort: "For noticing classroom management relevant situations in the video I afforded…" with the scale from "very, very low mental effort" to "very, very high mental effort."

After video viewing, the participants rated the task workload and task complexity (Kyndt et al., 2011) of their video viewing. Both scales were translated into German. There were 9 items for task workload on a 7-point Likert scale (e.g., "I found it a difficult task," $\alpha = 0.86$). Task complexity was divided into two dimensions à 2 items on a 5-point Likert scale: familiarity with the type of task (e.g., "I've undertaken similar tasks in the past. I was familiar with the design of the task," $\alpha = 0.89$) and availability and access to information (e.g., "I had too little information, information resources and aids at my disposal while completing this task," $\alpha = 0.73$).

4.4. Procedure

In the first part of the study – one week before participants joined the laboratory part – they answered the pedagogical-psychological knowledge test (PUW) by König and Blömeke (2010). In the second part of the study, the participants' gaze was recorded by a monitor-based Tobii Pro Eye-Tracker Nano with 60 Hz sampling rate (screen resolution: 1920 × 1,080). After ensuring that the participants were seated comfortably with a distance of about 60 cm to the monitor, the recording started with a 9-point calibration. Participants watched both videos consecutively. Before watching the first video, we provided a short definition about classroom management (Classroom management encompasses all actions a teacher takes to create and maintain an effective teaching-learning environment, Wolff et al., 2021) and information about the class in the first video for all participants. Then, the participants were given the task instruction depending on their condition. To be held comparable, we kept the different instructions similar in their wording and in their length of time. Only the timing of the presentation differed between the experimental conditions: while participants in the specific task instruction condition and in the general task instruction received instruction before video viewing – the participants of the prompting condition received instruction during video viewing. We tasked them in all conditions to press a mouse button each time participants would notice an important situation to mark time stamps as an indicator to their noticing. This method has already been proven effective in prior investigations (van den Bogert et al., 2014; Stahnke and Blömeke, 2021; Grub et al., 2022a,b). For the second video, we repeated the procedure by providing information about the video and showed the same instructions as before. After each video, participants were asked about their mental effort (Paas, 1992).

Right after video viewing, we conducted retrospective interviews. The verbal data was recorded. We replayed the videos and stopped every time the participant had marked them with a time stamp. The question for the interview in every situation was: "Why did you consider this situation as relevant for classroom management?." We asked no additional questions nor added information. As a last part of the study, participants received the questionnaire asking for task complexity and task workload (Kyndt et al., 2011) and further demographic information. For each participant, the study protocol took around 35–45 min to complete.

4.5. Analyses

For the data on the outcome level, we counted the number of mouse clicks for each participant and triangulated them with interview data. This methodological approach was also used in prior investigations (Muhonen et al., 2021, 2023; Grub et al., 2022a,b). Two research assistants transcribed the recordings and coded how many clicks were related to classroom management. Other clicks were coded as irrelevant separately and did not negatively affect the total number of relevant clicks. Each statement was considered as a coding unit. In some cases, participants mentioned two or more aspects in one statement. Each aspect was coded separately. They double coded a random subset of 10% of the transcribed data. An intraclass correlation coefficient (ICC) was calculated for the number of relevant clicks [ICC = 0.844, 95% CI 0.710, to 0.919, ($p = < 0.001$)]. Due to this high level of agreement (Greguras and Robie, 1998), the remaining material was evenly split and individually coded by both coders.

Shapiro–Wilk tests indicated that some measures were non-normally distributed. To account for the non-normal distribution, we performed Kruskal-Wallis tests. We used IBM SPSS 28 as a statistical software to analyze the data quantitatively.

4.5.1. Research question 1

For hypotheses 1a and 1b, we chose six specific situations in our analysis: these were the situations that were highlighted by the specific task instruction before video viewing and by the prompts right during video viewing. For this reason, we considered two situations about smoothness and momentum, two situations about the teachers' management with disruptions, and two situations about the teachers' omnipresence. Participants received one point for each time they clicked on these situations or mentioned them in the interview. Overall, participant scores could range from 0 to 6.

4.5.2. Research question 2

With the analysis of eye-tracking data, we wanted to gain further insights to the participants' visual focus of attention on a process level. Therefore, we used the gaze recordings during the video viewing and analyzed them with Tobii Pro Lab software (v. 1.123). Due to stationary eye tracking, we set the velocity threshold filter (IVT) to 30°/s. We excluded $n = 2$ participants from the analysis due to their angular deviation being higher than 1° in terms of data quality. As suggested by Pappa et al. (2019), we hand-coded all areas of interest (AOIs) as contouring areas. In contrast to rectangular AOIS, contouring AOIs are more reliable and less prone to incorrect fixations (Pappa et al., 2019).

For reasons of work economy, we chose two situations of the video material to analyze the participants' gaze. The first situation showed disruptive student behavior. We analyzed a video sequence (20.58 s) of the first video where the class can be seen from the front view. In this moment, the teacher is explaining the next task but many of the students do not listen to him. The teacher is trying to intervene by changing his position toward two talking students in the first row and by raising his voice. For hypotheses 2a–d, we set the AOIs for the students showing disruptive behavior. We analyzed the *number of fixations* as well as the *time to first fixation* (in milliseconds) for these AOIs.

The second situation (14.75 s) occurred in the second video and showed the teachers' omnipresence in the classroom. In a peer learning phase, the teacher is walking through the classroom and stops by every partner group to make sure that the students have understood the task and that they are working on the task. For hypotheses 2e–j, the AOIs are set for the students, the teacher, and the material in the classroom. We analyzed the *number of fixations* and the *fixation duration* (in milliseconds) for each AOI group (students, teacher, material) as well as the *GRI*.

4.5.3. Research question 3

Going further, we analyzed the interview data qualitatively in terms of the question: which strategies of classroom management do participants notice? With this analysis, we want to determine which aspects the participants perceived as relevant as a first exploratory approach to investigate the salience of classroom management situations. For this analysis, we selected $n=45$ participants from the control condition (general task) because their instructional format did not influence them about any specific classroom management strategies. For the situations participants identified as relevant for classroom management, we elaborated seven thematical categories and developed a coding scheme both inductively (Kounin, 2006; Ophardt and Thiel, 2017) and deductively (Kuckartz, 2012). The categories are: (A) management with disruptive behavior, (B) smoothness and momentum, (C) omnipresence and overlap, (D) group mobilization, (E) variety and challenge, (F) rules and routines, and (G) other classroom management aspects (see Figure 1).

5. Results

5.1. Control variables

To avoid external group influences on the dependent variables, we asked for mental effort after each video, task complexity, task workload, and prior pedagogical-psychological knowledge. We had to remove one participant from data analysis due to technical problems in the data transmission of the questionnaire. Regarding mental effort, the participants stated to invest rather high mental effort in the video viewing ($M=5.21$; $SD=1.08$). The task workload was moderate for all participants ($M=3.02$; $SD=0.88$). Regarding task complexity, participants stated to be familiar with the task of video viewing ($M=2.72$; $SD=1.59$). In addition, they also stated to have moderate access to information ($M=2.61$; $SD=1.36$). Regarding prior pedagogical-psychological knowledge, the participants could reach a value between 0 and 1 and had a mean value of $M=0.49$ ($SD=0.12$). Groups did not differ significantly on these control measures (see Table 1).

5.2. Effects of different task instructions on noticing outcomes

The first aim of the study was to investigate whether different instructional settings have an influence on noticing classroom management situations on an outcome level. For this, we took the number of identified situations into account by counting and triangulating the mouse clicks with verbal reports. Across both videos, participants made on average $M_{rel}=7.30$ ($SD=4.61$) relevant clicks and $M_{irrel}=8.97$ ($SD=4.84$) irrelevant clicks. The ratio between relevant and irrelevant clicks was rather small in the general task condition (0.69) in contrast to the specific task condition (0.83) and the prompting condition (0.94).

To test our hypotheses, we concentrated on six relevant situations. Table 2 presents the mean number and standard deviation estimates of relevant clicks for each instructional condition. We expected no differences between the prompting and specific task condition (H1a), but a higher number of relevant clicks for each experimental condition in contrast to the control condition (H1b). Findings from a Kruskal-Wallis-test showed that the three conditions differed significantly from each other [χ^2 (2) = 19.771, $p<0.001$]. As expected in hypothesis 1a, the prompting condition did not differ significantly from the condition with a specific task $U=845.00$, $Z=-1.393$, $p=-0.166$. However, as expected in hypothesis 1b, both experimental conditions – the prompting condition ($U=516.00$, $Z=-4.110$, $p<0.001$; $r=0.43$) and the specific task condition ($U=617.50$, $Z=-3.305$, $p<0.001$; $r=0.35$) – differed significantly from the control condition.

5.3. Effects of different task instructions on visual attention

The second aim of the study was to investigate whether different instructional settings had an influence on noticing on a process level.

	Category	Definition	Example
A	Management with disruptive behavior	This includes all actions of the teacher – whether successful or not – that deal with disturbances, conflicts, behavior modification, or discipline in order to return or maintain teaching and learning activities. (Ophardt & Thiel, 2017)	"I think he didn't pay attention to whether the others were quiet or not, he just kept talking and maybe many people just don't understand him anymore. He had to pay a little more attention to that" (Participant anonymized, retrospective Interview, 12th Dec 22).
B	Smoothness and Momentum	All actions of the teacher – whether successful or not – to ensure a smooth lesson flow and continued engagement with the learning activities, especially in transitional phases. (Kounin, 2006)	"Now he doesn't perceive something like that [disruptive behavior] ... It's just not a smooth process if he has to write that down first when he could have done that before... That's why he doesn't perceive something like that, he has to write first and loses focus, and so the students lose focus." (Participant anonymized, retrospective Interview, 14th Dec 22).
C	Omnipresence and Overlap	All actions– whether successful or not – teachers make clear to the students that they are always aware of the situation in the classroom and will intervene if necessary as well as the teachers' focused attention on several events at the same time. (Kounin, 2006)	"So, the students feel like they're being watched, but not in a negative sense… the teacher sees what they're working on, and she's just trying to give hints and make sure it's understood. It doesn't come across as checking, it just comes across as giving advice." (Participant anonymized, retrospective Interview, 14th Dec 22).
D	Group Mobilization	All actions of the teacher – whether successful or not – to focus on the group as a whole and at the same time, to support students individually. (Kounin, 2006)	"She calls everyone up, includes everyone and thus she gets less disturbing behavior, because everyone could be called up, everyone could be taken up and everyone really participates. It's not: One student tells the story and the rest have to listen." (Participant anonymized, retrospective Interview, 21st Dec 22).
E	Variety and Challenge	All actions of the teacher – whether successful or not – to design learning activities that are experienced as varied and challenging in order to focus the students' attention. (Kounin, 2006)	"I found the idea really good that she took the students away from their normal place and created a bit of a new situation, with the semicircle to introduce a new topic. I actually found that good and also that she let the students organize themselves, so that they called each other and actually took himself really back and listened or just nodded when it was right." (Participant anonymized, retrospective Interview, 12th Dec 22).
F	Rules and Routines	All actions of the teacher – whether successful or not – to set up and maintain rules, procedures, and routines in order to establish social order in the classroom. (Ophardt & Thiel, 2017)	"I thought it was good that the teacher asked the students to stand up to greet each other, so that the students know that class is about to begin. I think that standing up is a better signal than remaining seated." (Participant anonymized, retrospective Interview, 11th Jan 23).
G	Other aspects of classroom management	All other actions of the teachers – whether successful or not –that help create a positive learning atmosphere and provide maximum learning time.	"She has communicated nonverbally and has only shown that they should please call themselves." (Participant anonymized, retrospective Interview, 8th Dec 22).

FIGURE 1
Category system for relevant classroom management situations with definitions and examples.

TABLE 1 ANOVA findings for control variables.

	N	*df*	*F*	*p*
Mental effort	134	2	0.07	0.93
Task workload	134	2	0.12	0.89
Task complexity Familarity with the task Access to information	134 134	2 2	0.03 0.07	0.97 0.94
Pedagogical-psychological knowledge	133	2	0.45	0.64

TABLE 2 Mean number of relevant clicks.

	N	*M*	*SD*
Prompting condition	45	2.31	1.28
Specific task condition	45	1.96	1.11
General task condition	45	1.18	1.13

TABLE 3 Number of fixations and time to first fixation for situation 1.

	Number of fixations			Time to first fixation	
	N	*M*	*SD*	*M*	*SD*
Prompting condition	44	2.31	1.28	324.43	58.45
Specific task condition	45	1.96	1.11	340.05	34.67
General task condition	44	1.18	1.13	338.65	35.00

Time to first fixation in milliseconds.

TABLE 4 Number of fixations, fixation duration and GRI for situation 2.

		Number of fixations		Fixation duration		GRI	
	N	*M*	*SD*	*M*	*SD*	*M*	*SD*
Prompting condition	44	3.65	1.11	115.83	30.08	33.82	12.08
Specific task condition	45	3.57	1.04	121.60	36.21	35.60	11.46
General task condition	44	3.39	1.13	129.83	38.45	41.08	14.54

Fixation duration in milliseconds.

For the first situation, we expected no differences between the prompting and the specific task instruction (H2a), but higher fixation counts of each experimental condition in contrast to the control condition (H2c). The participants of the prompting condition had on average higher fixation counts on students showing disruptive behavior than participants of the other conditions (see Table 3). The findings indicated a significant difference between these three groups (χ^2 (2) = 9.273, p = 0.010). Further tests showed a significant difference between the prompting condition and the control condition (U = 619.00, Z = −2.911, p = 0.004; r = 0.31). Therefore, hypothesis 2a could fully and hypothesis 2c partially be supported.

Moreover, we tested whether there was a difference between the mean values of the conditions regarding the time to first fixation of disruptive student behavior (see Table 3). Here, we neither expected a difference between the prompting and the specific task instruction (H2b), but a faster time to first fixation of participants of each experimental conditions in contrast to the control condition (H2d). Further non-parametric tests showed that there was – contrary to our hypothesis 2b – a significant difference between the prompting condition and the condition with specific task instruction U = 677.00, Z = −2.569, p = 0.010; r = 0.27. Yet, the specific task instruction condition did not differ significantly from the control condition (U = 823.00, Z = −1.366, p = 0.172), nor did the prompting condition differ significantly from the control condition (U = 870.00, Z = −0.818, p = 0.413). Therefore, hypothesis 2d was rejected.

In the second situation, we analyzed the parameters: fixation durations, fixation counts, and the gaze relational index (see Table 4). Here, we expected no differences between the prompting and the specific task instruction (H2e, H2f, H2g), but shorter fixation durations (H2h), higher fixation counts (H2i), and a lower gaze relational index (H2j) in both experimental conditions in contrast to the control condition. Regarding average fixation duration, there was no significant difference between conditions [F (2,132) = 2.176; p = 0.175]. There neither was a significant difference between the conditions regarding average fixation counts [F (2,132) = 0.624; p = 0.538]. While hypotheses 2e and 2f could be supported, hypotheses 2h and 2i needed to be rejected. Putting these two parameters in relation, the gaze relational index differed significantly between conditions [F (2, 132) = 3.879; p = 0.023]. Here, the participants of the prompting condition showed a similar gaze index as the participants of the specific task condition and did not differ significantly [t (2,87) = 0.232, p = 0.476]. Moreover, the prompting condition differed significantly from the control condition [t (2,86) = 2.549, p = 0.013; r = 0.27]; the condition with specific tasks also differed significantly from the control condition [t (2,87) = 1.976, p = 0.048; r = 0.21]. Consequently, hypotheses 2g and 2j were supported.

5.4. The salience of classroom management situations

To address the question about the salience of classroom management situations, we examined participants' verbal data more closely in terms of classroom management strategies (RQ3). This exploratory approach can provide first insights into the question which classroom management situations are more or less salient to pre-service teachers and in which situations pre-service teachers should be instructionally supported to enhance their professional vision. We examined seven classroom management categories (see Figure 1). Table 5 shows that participants most frequently identified situations of the teachers' omnipresence (Category C), followed closely by the situations of group mobilization (Category D). In contrast, situations involving disruptive behavior (Category A) and about variety and challenge (Category E) were identified less frequently.

6. Discussion

In this study, we tested three instructional formats: a specific task before video viewing and prompts during video viewing – compared to a general task instruction. We expected a specific task instruction

TABLE 5 Number of identified of classroom management situations.

Categorization of classroom management situations	Number of situations identified
Management with disruptive behavior	24
Smoothness and momentum	48
Omnipresence and overlap	64
Group mobilization	61
Variety and challenge	24
Rules and routines	53
Other aspects of classroom management	27

to have a similar attention directing effect as prompts during video viewing. To investigate the instructional effects on professional vision, we analyzed data on an outcome and a process level.

6.1. Overview of findings

On the outcome level, both experimental conditions differed significantly from the general task instruction (H1b). Strengthening previous investigations (Gabel and Gegenfurtner, 2023), the specific task condition and the prompting condition showed a similar number of identified events and did not differ significantly (H1a). These findings support the assumption that both instructional settings support schema activation and support professional vision – regardless of the time they are provided (Grub et al., 2022a,b; Martin et al., 2023).

On a process level, both experimental conditions foster visual monitoring in the second situation (H2g), where the teacher is walking around the classroom and making sure that the students work on their tasks. Here, the pre-service teachers of the experimental conditions showed a lower GRI than pre-service teachers of the control condition (H2j). Previous investigations found similar findings for the group with specific task instruction (Grub et al., 2022b). This implies a more global monitoring behavior and is an indication for visual expertise (Gegenfurtner et al., 2020). However, in a critical situation where students show disruptive behavior, we revealed different findings at the process level: the prompting condition's priming effect appears to better direct visual attention in disrupting situations. Participants in the prompting condition show a higher number of fixations and a faster time to first fixation (H2e, H2f, H2h, H2i). The prompts seem to activate information that were not previously available shortly before the event (Berthold et al., 2007; Bannert, 2009). Due to the timing of the prime stimulus, pre-service teachers can better focus their attention on the relevant situations. This suggests that, in critical situations of classroom videos, prompts that are provided shortly before this event occur are a more effective form of instruction to guide pre-service teachers' attention and facilitate top-down processing.

Investigating the identified classroom management strategies qualitatively, participants mostly perceived strategies in which the teacher shows omnipresence as well as actions for group mobilization (RQ3). Hence, pre-service teachers seemed to view the teacher's appearance in the video as a crucial component of effective classroom management – and thus, perceive as more salient. At the same time, they tend to focus less on the management with students' misbehavior. Concluding – and agreeing with the results of the outcome level – pre-service teachers might perceive especially (the handling of) critical situations as complex.

6.2. Limitations and further directions

Before turning to our conclusion, we need to point out some limitations of this study. The sample consisted of a large number of first-year students. Even after controlling for variables like prior knowledge and task difficulty, we cannot completely rule out bias in the results given that participants were mostly in an early stage of their studies. However, in prior research, Grub et al. (2022b) compared different instructional settings to pre-and in-service teachers and identified an attention-guiding effect of specific instruction on monitoring behavior – regardless of expertise level. Nevertheless, it is possible that the instruction should be adjusted depending on prior knowledge. Therefore, a replication with students from different semesters and with different levels of prior knowledge would be interesting to investigate the need of instructional adaptation. In addition, it would be interesting to conduct a study with experienced teachers and contrast in-service with pre-service teacher assessments. Another important aspect to be considered is the length of the videos: if the specific task is shown before the video, the pre-service teachers should still be able to keep the task in mind. We used two videos of medium length (both of about 04:30 min). For this reason, our results are limited to videos of a medium length: it cannot be guaranteed that the specific task instruction is as effective as the presentation of prompts for classroom videos with a longer duration. Moreover, we have selected instructional videos from two subjects – a science lesson and a language lesson. For this reason, it is difficult to generalize the findings to all subjects. Further, we linked the instructional settings to the field of classroom management. It is likely that the findings differ depending on other observation contexts, such as didactical foci. We suggest a replication study with videos in other subjects and invite future research to examine whether the instructions need to be adapted for different disciplinary fields.

6.3. Practical implications

Noticing relevant classroom management situations is an important competence for pre-service teachers (Gold et al., 2017; Grub et al., 2020; van Es and Sherin, 2021). However, without instructional guidance, pre-service teachers are struggling with noticing relevant events (Santagata et al., 2021; Grub et al., 2022b). Our findings tend to indicate that teacher educators can implement both, a specific task instruction before video viewing or prompts during video viewing in pre-service teacher education. The decision which instructional setting to choose may depend on task economy vs. identification of disruptive student behavior. On one hand, when concerned with task economy, a specific task before video viewing is arguably easier to implement and less work-intensive than implementing prompts in a video player. On the other hand, when concerned with identification of disruptive student behavior, prompts prior to student misbehavior tends to help pre-service teachers to focus on these critical classroom management events – which is particularly important because our qualitative analyses suggests that pre-service teachers mainly struggle to identify critical situations such as (teachers' management with) disruptive student behavior.

6.4. Conclusion

Classroom videos become increasingly important in pre-service teacher education (Gaudin and Chaliès, 2015). With this opportunity – to provide pre-service teachers with teaching scenarios – however, emerges a need for optimal instructional guidance (Grub et al., 2022a,b; Martin et al., 2023). Our study contributes to this research gap by testing different instructional formats. Findings indicate that instructional formats should be adapted to the intentions of video viewing. Prompts need to be implemented and to be adjusted to certain time stamps or events during the video. In contrast, a specific task instruction can be shown prior to video viewing – appearing to have a similar attention-guiding effect and is more economic for educators to promote professional vision. However, on a process level, prompts seem to better guide attention, when it comes to critical classroom situations in the video. Therefore, educators should choose an instructional format depending on the situations of video viewing: participants seem to attend to general classroom management situations on a similar level when provided a specific task instruction prior to video viewing, whereas critical situations seem to better be monitored by prompts due to their priming effect. In a subsequent qualitative analysis, we examined which classroom management situations are more or less salient for pre-service teachers in order to support their professional vision for these situations. Consistent with the previous quantitative analyses, we found that pre-service teachers notice classroom management strategies addressing teachers' management with disruptive behavior less often than other situations. This finding indicates that instructional support needs to be adapted to identify and interpret different classroom situations in terms of their salience.

Data availability statement

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

Author contributions

SG: Conceptualization, Formal analysis, Methodology, Writing – original draft. ÖK: Writing – review & editing. IK: Writing – review & editing. DL: Writing – review & editing. AG: Conceptualization, 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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Teaching practices mediating the effect of teachers' psychological stress, and not physiological on their visual focus of attention

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The aim of the present study was to investigate the association between teachers' ($N = 53$) physiological and psychological stress and their visual focus of attention as well as the mediating effect of teaching practices on this association in authentic classroom settings. Data were collected using multimodal methods of measurement: salivary cortisol levels for physiological stress, a self-reported questionnaire for psychological stress, observed teaching practices during one school day, and eye-tracking video recordings of classroom teachers during one lesson for teachers' visual focus of attention. The results showed that neither teachers' physiological nor psychological stress was directly related to their visual focus of attention. However, using more child-centered teaching practices compared with teacher-directed ones was related to a higher number of fixations on students, longer total fixation duration, and more individualized distribution of visual focus of attention on students. Teacher's teaching practices mediated the effect of teachers' psychological stress on their fixation counts on students and distribution of visual focus of attention. The results suggest that teaching practices are related to the visual attention teachers' give to students and that teachers' stress affects their visual focus of attention through teaching practices. The practical implications of this study suggest that teachers should receive training and support to recognize their stress level and its association with their teaching.

KEYWORDS

teacher stress, teaching practices, teacher visual focus of attention, cortisol, eye-tracking, Grade 1

1 Introduction

Teachers need to manage several unpredictable classroom situations and the demands arising from them during the school day. Accordingly, teachers need to give immediate visual focus of attention and interact with students involved in these situations to assess their learning-related needs and behaviors. It has been reported that teachers' perceptions of their work-related stress are linked to the way they interact with students. For instance, when teachers are highly stressed, they tend to offer less emotional support to students and show lower quality of classroom organization (Penttinen et al., 2020). They also give less individualized visual focus of attention to the students (Chaudhuri et al., 2022a). Furthermore, teachers who report experiencing less stress tend to give more attention to students' individual learning experiences, respond more to students' needs, and use less reactive classroom management strategies (Clunies-Ross et al., 2008; Turner and Thielking, 2019).

Unpredictable situations often occur during teaching in authentic classroom settings and it might be demanding for teachers to give immediate visual focus of attention to students in order to notice relevant information and monitor moment-to-moment changes in students' learning-related behaviors (Van den Bogert et al., 2014). Accordingly, teachers need to adjust their teaching practices and provide adaptive pedagogical support based on the needs of their students (Seidel et al., 2021). However, we are far from understanding how teachers' stress is related to their teaching practices and classroom behavior toward students. Previously, laboratory-based studies have shown that relationships exist between stress and cognition, and visual gaze behavior and stress. For instance, Buchanan et al. (2006), argued that physiological stress can negatively influence cognition in terms of memory responses in a word recall test. In addition, Vatheuer et al. (2021) argued that an individual typically shows visual gaze avoidance during a strong cortisol response in socially stressful situations. The researchers of the mentioned study have warranted the use of eye-tracking to detect the effects of stress on social interaction situations.

Similarly, teaching involves social interactions between teachers and students whereby the teacher must encourage student's participation, manage challenging student behaviors, and monitor academic developments among other social activities in authentic classroom settings. Previous research has shown that teachers' high work-related stress is associated with less individualized visual focus of attention on students in authentic classroom settings (Chaudhuri et al., 2022a). In addition, Jõgi et al. (2023a) showed that there were no relationships between physiological stress and positive affect in authentic classroom settings. However, teachers' self-efficacy beliefs were related to lower stress and higher positive affect in the middle of the school day. Furthermore, Jõgi et al. (2023b) showed that teachers' physiological stress did not have an effect on teachers' teaching practices or student's learning outcomes. However, Jõgi et al. (2023b) argued that teachers with lower self-reported stress used relatively more child-centered teaching practices than teacher-directed ones. The present study is different from the previously conducted studies as we are investigating how teachers' psychological (self-reported) and physiological (cortisol levels) stress in the classroom are related to teachers' visual focus of attention in authentic classroom settings and whether teacher's teaching practices mediate this association.

1.1 Teachers' stress

Teaching is a stressful occupation due to high pressure and many demands, novel tasks, and recurring problems which need to be solved in the classroom (Johnson et al., 2005; Broughton, 2010). Many teachers experience the feeling that they do not have enough time and resources to do their work the way they want to (Aulén et al., 2021). In addition, disruptive student behaviors (Clunies-Ross et al., 2008) or less supportive leadership cause strain in the teaching environment (Skaalvik and Skaalvik, 2009). Therefore, teachers typically report higher levels of stress than many other professionals (Aloe et al., 2014; Herman et al., 2020). Stress is harmful, as higher stress is linked to greater burnout (e.g., Pogere et al., 2019) and higher turnover intentions among teachers (Skaalvik and Skaalvik, 2011; Madigan and Kim, 2021). Furthermore, stressed teachers also use fewer child-centered teaching practices in the classroom (Jõgi et al., 2023b) and have poorer relationships with their students (Aldrup et al., 2018). However, less is known about how teacher stress and teaching practices are associated with their visual focus of attention while teaching.

Teacher stress can be categorized as a subjective experience (psychological stress) or a physiological stress. The latter can be objectively assessed while the former, which is often based on self-ratings, is a subjective evaluation of challenges in the teaching environment and an individual's abilities to cope with these (Schlotz, 2019; Becker et al., 2022). In the present study, teachers' physiological stress was measured by salivary cortisol, the most suitable way to collect cortisol samples non-invasively in ambulatory settings. Cortisol is released in the body through the hypothalamic–pituitary–adrenal axis when a person gets into a stressful situation and the sympathetic nervous system is activated (Kudielka et al., 2012). Higher daytime cortisol levels are characteristic of people under chronic stress (Miller et al., 2007) and can be a risk factor for several psychological and physiological malfunctions, for example, increased anxiety or suppression of the immune system (Chrousus, 2009). Recent research results suggest that self-reported stress and physiological stress are two different facets of stress that might not be correlated (Katz et al., 2016; Becker et al., 2022). Therefore, in the current study, both indicators of stress were investigated to obtain a more complete picture of teachers' stress-related experiences at work—including both the physiological and psychological measures of stress.

1.2 Teaching practices

The development of primary school students' academic skills and motivation depend on practices their teachers choose to use (Lerkkanen et al., 2012, 2016; Kikas et al., 2018; Pakarinen and Kikas, 2019; Tang et al., 2022). Teachers differ in terms of the teaching practices they deploy in the classroom (Lerkkanen et al., 2016; Tang et al., 2017; Kikas et al., 2018). A common theoretical framework for studying teaching practices is treating them as child-centered and teacher-directed ones, which have roots in constructivism and behaviorism, respectively (Daniels and Shumow, 2003; Stipek and Byler, 2004). Child-centered teaching practices emphasize children's active participation, addressing children's needs, interests, and initiatives, and teacher's active scaffolding of children's learning. Teachers using teacher-directed practices typically give the same instruction and tasks to all students and emphasize correct answers rather than the learning process (Stipek and Byler, 2004). In practice, most teachers employ both child-centered and teacher-directed practices depending on the goal of learning task, but teachers differ in the ratio of using one or another (Daniels and Shumow, 2003). Subsequently, during teaching, teachers' visual focus of attention toward students in the classroom can vary based on student- related factors such students' basic academic skills, individual support for students in basic academic skills, and students' behavior toward the teacher (Goldberg et al., 2021; Chaudhuri et al., 2022b). Although several studies have examined the role of teaching practices in student outcomes, less is known how teaching practices are associated with teachers' visual focus of attention while teaching. It is noteworthy that although both teaching practices and teachers' visual focus of attention are measured from authentic classroom settings, yet, they are two different constructs. Teaching practices measure the ratio of child-centered versus teacher-directed practices based on the learning task whereas teachers' visual focus of attention measures teachers' classroom behavior in terms of duration of visual gaze toward students during teaching.

1.3 Teacher visual focus of attention

Teacher visual focus of attention has been defined as the teacher's gaze on relevant targets in the classroom, such as students, to process information related to their learning and behavior during teaching in authentic classroom settings (van den Bogert et al., 2014). The classroom is an information-dense environment in which multiple unforeseen situations arise that require the teacher's immediate visual attention. Despite the unforeseen demands in the classroom environment, teachers need to notice students in order to assess their learning-related behaviors and adjust their instruction accordingly (Jarodzka et al., 2021).

Previous research has shown that all students in a classroom receive the teacher's visual attention; however, the amount of it varies (Dessus et al., 2016). There are many student-related factors, such as academic skill levels and classroom behavior, that can determine the amount of teacher visual focus of attention toward students. For instance, teachers direct a longer visual focus of attention to students with poor basic academic skill levels in order to provide more individual and adaptive pedagogical support to the students (Seidel et al., 2021; Chaudhuri et al., 2022b). Furthermore, teachers direct longer visual focus of attention to students showing more interactive, disruptive, and off-task behavior during a lesson (Yamamoto and Imai-Matsumura, 2013; Goldberg et al., 2021; Shinoda et al., 2021). In addition, teacher-related factors, such as perceived stress at work, can affect their visual focus of attention in the classroom. For example, higher teachers' stress in terms of their perceived inadequacy is associated with less individualized visual focus of attention on students in the classroom (Chaudhuri et al., 2022a). In summary, there is evidence that teachers' perception of stress can be related to their classroom behavior in terms of visual focus of attention on students. However, little is known about the way teachers' physiological and psychological stress are related to teachers' visual focus of attention through their teaching practices.

1.4 Aim of the study

We expand on the previous findings by addressing three important issues. First, we are far from understanding how teachers' physiological and psychological stresses are related to the way they allocate their visual focus of attention in the classroom. Second, the role that teaching practices play in teachers' visual focus of attention has been less investigated. Third, it is unclear whether teaching practices mediate the association between teachers' stress and visual focus of attention. We used multimodal data collection methods to increase the ecological validity strongly recommended in teachers' well-being research (Francis et al., 2017; Hascher and Waber, 2021). Our theoretical model is presented in Figure 1, and our specific research questions (RQ) and hypotheses (H) are the following:

> *RQ1*: To what extent are teachers' physiological and psychological stresses related to their visual focus of attention in the classroom?
>
> *H1*: We expected that higher physiological and psychological stress would be related to less individualized distribution of visual focus of attention and fewer attention fixations on students (Chaudhuri et al., 2022a).
>
> *RQ2*: To what extent are teachers' teaching practices related to their visual focus of attention in the classroom?
>
> *H2*: We expected that using more child-centered practices compared with teacher-directed ones is related to more individualized distribution of visual focus of attention and more fixations on students (Goldberg et al., 2021; Seidel et al., 2021).
>
> *RQ3*: Do teaching practices mediate the effect of teachers' stress on their visual focus of attention?
>
> *H3*: We expected that teachers' higher physiological and psychological stress would be related to their visual focus of attention in the classroom through employing less child-centered teaching practices compared with teacher-directed ones (Chaudhuri et al., 2022a; Jõgi et al., 2023b).

2 Methods

2.1 Participants

In the present study, 53 teachers (3 males) teaching Grade 1 from 31 schools and seven municipalities of Central Finland located in both rural and urban areas participated. The teachers reported their work experience in years ($M_{exp} = 16.07$, $SD = 9.43$, $Min_{exp} = 0.5$, $Max_{exp} = 39$) and their class size ($M_{cs} = 19.3$, $SD = 4.34$, $Min_{cs} = 7$, $Max_{cs} = 25$). The data used in the study were part of a larger project that focused on the role of teacher and student stress on teacher–student interactions in

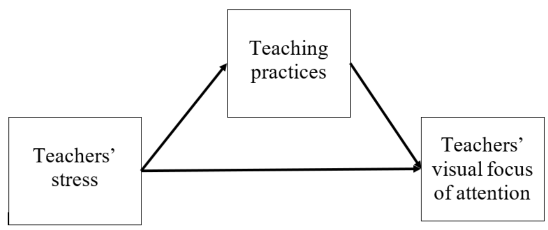

FIGURE 1
Theoretical model hypothesized in the study.

the classroom (Lerkkanen and Pakarinen, 2021). The study was approved by the university ethics committee before the data collection began, and it was determined to be in line with the Finnish National Board on Research Integrity (TENK, 2012). Teachers were informed that participation in the study was voluntary. Teachers, as well as their students' parents, gave written consent for their participation prior to data collection.

2.2 Measures

2.2.1 Teachers' physiological stress

We used saliva cortisol as teachers' physiological stress indicator. Teachers were asked to give six saliva samples during two working days: at awakening, 30 and 45 min after awakening, at 10:00 a.m., at the end of the school day at approximately 12:00–1:00 p.m., and before bedtime. Salivette® Cortisol swabs (Sarstedt, Nümbrecht, Germany) were used for collecting saliva samples. Samples were assayed by Cortisol Luminescence Immunoassay (CLIA RE62011; IBL International Corp.) in Dresden LabService GmbH, Germany. According to our protocol, a cortisol sample was excluded if the teacher had eaten within 30 min before sampling or had been ill on the sampling day. We also excluded cortisol samples with concentrations larger than 73 nmoL/L as physiologically implausible (Miller et al., 2013).

In the current study, we used samples from two time points during or after the lessons, at 10:00 a.m. and at approximately 12:00–1:00 p.m. For both samples, cortisol levels from two sampling days were averaged (Wolf et al., 2008; Massey et al., 2016). Higher cortisol levels have been interpreted as indicating higher physiological stress (Miller et al., 2007; Berry et al., 2014).

2.2.2 Teachers' psychological stress

An adapted version of Gerris's Parental Stress Inventory (Gerris et al., 1993; Pakarinen et al., 2010) was used to measure teachers' teaching-related psychological stress. The self-reported questionnaire consisted of three items about teaching-related stress (e.g., "I have a lot more problems in guiding the children than I expected."; "I often feel guilty or inadequate when thinking about what kind of teacher I am." and "I sometimes feel that guiding children is an overwhelming task for me."; Cronbach's alpha = 0.76.) which were rated on a 5-point Likert scale (1 = "Does not apply to me at all" and 5 = "Applies to me very well"). The average score of the three items was calculated and used as a psychological stress indicator.

2.2.3 Teachers' teaching practices

Teaching practices were measured using the Early Childhood Classroom Observation Measure (ECCOM; Stipek and Byler, 2004; Tang et al., 2017). Teachers employing child-centered and teacher-directed practices in their classrooms were rated by trained research assistants from three video-recorded lessons of 45 min from one school day. The dimensions of teaching practices were assessed based on three subscales: classroom management (4 items), classroom climate (4 items), and instruction (7 items), rated on a 5-point scale (see Appendix 1 for table showing description of subscales). The scale points on each of these items show the percentage of instructional time teacher used child-centered or teacher-directed teaching practices (1 = '0–20%' of time, 5 = '81–100%' of time). The mean of all items from all the three sub-scales were used to estimate child-centered and teacher-directed practices (see also Tang et al., 2017). Previous research has shown that teachers employ child-centered and teacher-directed practices during teaching, however, one of these practices are typically dominating (Daniels and Shumow, 2003; Stipek and Byler, 2004). Since child-centered and teacher-directed practices often show strong negative correlation such as $r = -0.89$ in the present study sample, these dimensions cannot be added as individual observed variables in the same statistical model due to multicollinearity. Accordingly, in the present study, the ratio of child-centered to teacher-directed practices was used in the analysis (see also Lerkkanen et al., 2012; Roubinov et al., 2020). A ratio score more than 1 indicated that the teacher implemented more child-centered practices whereas a ratio score of less than one meant that the teacher implemented more teacher-directed practices during teaching (Roubinov et al., 2020; Jõgi et al., 2023b). The inter-rater reliability was assessed based on 11 observations that were observed by two observers. There was good agreement between observers (intraclass correlation coefficient ICC[1] = 0.88 for child-centered practices and ICC[1] = 0.79 for teacher-directed practices). For further analyses, one out of the two observations was randomly chosen for each teacher. The mean of all items from all the three sub-scales were used to estimate child-centered and teacher-directed practices (Tang et al., 2017).

2.2.4 Teachers' visual focus of attention

Teachers' visual focus of attention was measured using mobile eye-tracking technology. Teachers wore Tobii Pro Glasses 2 (Tobii AB, Danderyd, Sweden) for 20–25 min from the beginning of the second lesson of a normal school day. The authentic classroom setting during the eye-tracking video recording was ensured by giving the teachers freedom to conduct the lesson the way they wanted. The teachers' eye-tracking videos were recorded during 20 literacy lessons, 26 math lessons, and four activity-based lessons. Furthermore, two trained research assistants calibrated the eye-tracking glasses using a one-point calibration before recording the eye-tracking videos. Thereafter, to ensure good data quality, the calibration was rechecked and validated by asking the teacher to look at three points on the wall. Only after successful calibration did the research assistants start the eye-tracking recording. After the eye-tracking videos were recorded, the fixations were filtered from the video recordings using the I-VT Attention filter setting of the Tobii Pro Lab v.1.128 analysis software. The I-VT Attention filter was best suited for identifying fixation metrics, as the participant's physical movements were not restricted while recording the eye-tracking videos. Each teacher's visual focus of attention was determined based on their areas of interest (AOIs) in the classroom. The AOIs were defined as the targets that the teacher looked at in the eye-tracking videos, such as students, instructional materials (such as those related to teaching and learning), and non-instructional materials (such as walls, curtains, tables, chairs, etc.). AOI codes have been previously determined and used in prior research (see Chaudhuri et al., 2022a,b). Furthermore, trained research assistants mapped fixations on the AOIs identified from eye-tracking video recordings using the Tobii Pro Lab v.1.128 software, based on where the teacher focused their visual attention. For example, teachers' gaze on an individual student was shown by a red circle on the video; then, the research assistant manually mapped the gaze on the respective student's picture and identified it as the teacher's AOI.

To ensure intercoder reliability, double coding was done with 20% of the videos from the whole dataset, which provided a double coding agreement average of 90.09%. Once the eye-tracking video recordings were coded, further analysis was conducted using the teachers' visual focus of attention in terms of the teachers' total fixation duration on students and fixation counts on students. Furthermore, to ensure good quality data, eye-tracking video recordings with a gaze sample percentage of 70% and above were selected. The gaze sample percentage is defined as the total percentage of the recording duration when one or both eyes are detected by mobile eye-tracking glasses. Accordingly, three videos from the present dataset had to be excluded due to a gaze sample percentage lower than 70%. The values of total fixation duration greater than 3 *SD* were excluded from the further analyses as outliers ($n = 2$).

2.3 Procedure

These questionnaires were given to the teachers on the same day they were instructed about the salivary cortisol sampling. The teachers filled out the questionnaires in their preferred time. Teaching practices were video-recorded on the first salivary cortisol sampling day by trained research assistants. Typically, on the same day as the video recording, the eye-tracking videos were recorded during the second lesson of the school day.

2.4 Analysis strategy

In the present study, fixation was defined as the time when the eye was relatively still and took input from the environment for information processing (Holmqvist et al., 2015). Accordingly, teachers' fixation metrics, such as total fixation durations and fixation counts, were considered as indicators of teachers' visual focus of attention and used for further analysis. Teachers' total fixation duration can be defined as the duration of time during eye tracking when the eye is relatively still and provides the ability to process information from the targets in the classroom environment (van den Bogert et al., 2014; McIntyre et al., 2017; Goldberg et al., 2021; Seidel et al., 2021). Additionally, fixation counts can be defined as the total number of times fixations occur in an AOI (such as students) in a given time period during an eye-tracking recording (Holmqvist et al., 2015). Next, in order to estimate teachers' distribution of visual attention among students, teachers' total fixation duration on students was used to calculate the Gini coefficient using the Gini package in R (Zhicheng et al., 2021). The Gini coefficient ranged from 0 to 1, wherein 0 referred to an equally distributed visual focus of attention on all students and 1 referred to an unequal distribution, wherein only one student received all the visual focus of attention (Cortina et al., 2015). In the classroom context, high teachers' total fixation duration and fixation counts on a student typically indicate that the teacher is processing information related to student characteristics (Seidel et al., 2021). According to Cortina et al. (2015), the high number of fixation counts on a student can typically occur when a teacher engages in providing feedback to an individual student.

Descriptive statistics and bivariate correlations were estimated using IBM SPSS 28.0 (IBM, Armonk, NY, USA). Path analyses with mediation were modeled using MPlus 8.8 (Muthén and Muthén, 1998–2022). Missing data was managed through a full information maximum likelihood (FIML) procedure that allows the inclusion of all available data into the model estimation.

In total, we conducted nine path analyses with regression. For each of three dependent variables of visual focus of attention (Gini coefficient, total fixation duration, fixation counts), we tested three path models with each of three stress indicators (psychological stress, cortisol at 10:00 a.m., cortisol at 12:00–1:00 p.m.) and teaching practices as independent variables. In all nine models, the direct paths from stress and teaching practices to the visual focus of attention indicator were estimated, and the indirect path from stress through teaching practices to attention was modeled. All nine models were identified with zero degrees of freedom and a perfect fit (Raykov et al., 2013).

3 Results

3.1 Bivariate associations between teachers' psychological and physiological stress, teaching practices, and visual focus of attention

The descriptive statistics of the study variables are indicated in Table 1. The bivariate correlations are shown in Table 2. The higher salivary cortisol levels of teachers at 10:00 a.m. were related to their higher cortisol levels at 12:00–1:00 p.m. All three visual focus of attention indicators also correlated in the expected directions. A higher Gini coefficient was related to shorter total fixation duration

TABLE 1 Descriptive statistics of stress, teaching practices, and visual focus of attention.

Indicator	*N*	*M*	*SD*	Min	Max
Psychological stress	52	2.16	0.74	1.00	4.00
Physiological stress					
Cortisol at 10:00 a.m. (nmol/l)[a]	53	2.29	0.55	1.20	4.24
Cortisol at 12:00–1:00 p.m. (nmol/l)[a]	53	2.15	0.45	1.10	3.48
Teaching practices[b]	53	1.33	0.76	0.30	3.70
Visual focus of attention					
Gini coefficient[c]	49	0.51	0.11	0.29	0.76
Total fixation duration (ms)	48	24,935.09	8,117.45	10,629.19	45,437.40
Fixation counts	50	61.65	23.57	27.64	134.00

[a]Cortisol concentrations are natural logarithm transformed and aggregated over two sampling days. [b]Ratio of child-centered practices to teacher-directed ones. [c]Distribution of teachers' visual focus of attention.

TABLE 2 Bivariate correlations between used indicators.

Indicator	1	2	3	4	5	6
1. *Psychological stress*	–					
Physiological stress 2. Cortisol at 10:00 a.m. (nmol/l)[a]	−0.01	–				
3. Cortisol at 12:00–1:00 p.m. (nmol/l) [a]	0.13	0.52***	–			
4. Teaching practices[b]	−0.43**	−0.05	−0.02	–		
Visual focus of attention 5. Gini coefficient[c]	0.12	0.15	−0.06	0.12	–	
6. Total fixation duration	−0.11	−0.20	0.03	−0.11	−0.57***	–
7. Fixation counts	−0.13	−0.13	−0.06	−0.13	−0.48***	0.60***

[a]Cortisol concentrations are natural logarithm transformed and aggregated over two sampling days. [b]Ratio of child-centered practices to teacher-directed ones. [c]Distribution of teachers' visual focus of attention. ** $p < 0.01$, *** $p < 0.001$.

TABLE 3 Regression model showing direct and indirect effects with variables such as cortisol at 10:00 am, visual focus of attention, and teaching practices.

	Visual focus of attention indicator					
	Gini coefficient[c] $R^2 = 0.12$		Total fixation duration $R^2 = 0.06$		Fixation counts $R^2 = 0.16$	
	β	p	β	p	β	p
Direct effects on visual focus of attention						
Cortisol at 10:00 a.m.[a]	0.10	0.282	**−0.16**	**0.029**	−0.09	0.329
Teaching practices[b]	**−0.33**	**0.001**	0.18	0.212	**0.39**	**<0.001**
Direct effect of cortisol on Teaching practices[b]	−0.04	0.713	−0.04	0.713	−0.04	0.710
Indirect effect of cortisol at 10:00 a.m. through Teaching practices	0.01	0.724	−0.01	0.735	−0.02	0.719

β, standardized regression coefficient. *p*, value of *p*. [a]Cortisol concentrations are natural logarithm transformed and aggregated over two sampling days. [b]Teaching practices-ratio child-centered teaching practices (CC) compared with teacher-directed practices (TD). [c]Distribution of teachers' visual focus of attention. Values in bold are significant.

and lesser fixation counts. A longer fixation duration was related to more fixation counts. However, no associations were found between teachers' psychological and physiological stress and teachers' visual focus of attention indicators.

Teachers' practices were related to their psychological stress, as teachers reporting lower stress used more child-centered practices in the classroom compared with teacher-directed ones. Teaching practices were not correlated with visual focus of attention indicators (Table 2).

3.2 Teaching practices mediating the association between teachers' psychological stress and visual focus of attention

Next, we tested nine separate regression models, in each of which one of three stress indicators explained one of three visual focus of attention indicators through teachers' teaching practices (see Tables 3–5). We found that neither teachers' psychological nor physiological stress was directly related to the teachers' visual focus of attention, except in one case. The higher the teachers' cortisol level in the middle of the school day, the less attention they paid to students in the classroom ($\beta = -0.16$, $p = 0.029$; see Table 3). There was a direct effect of teaching practices on the Gini coefficient (distribution of teacher visual focus of attention) and fixation counts. Teachers' use of more child-centered teaching practices compared with teacher-directed ones was related to the more individualized distribution of visual focus of attention (β-s $= -0.33 \ldots -0.36$, $p = 0.001 \ldots 0.007$) and a greater number of fixations or fixation counts on individual students (β-s $= 0.39 \ldots 0.46$, $p < 0.001$; see Tables 3–5).

We also tested the indirect effect of teachers' stress on visual focus of attention through their teaching practices. We found an indirect effect of teacher's psychological stress on teachers' visual focus of attention through their practices (see Table 5). Teaching practices mediate the association between teachers' psychological stress and their distribution of visual attention ($\beta = 0.16$, $p = 0.034$) and number of fixations ($\beta = -0.21$, $p = 0.009$). However, there were no indirect effects of teachers' physiological stress on teachers' visual focus of attention (see Tables 3, 4).

TABLE 4 Regression model showing direct and indirect effects with variables such as cortisol at 12:00–1:00 p.m., visual focus of attention, and teaching practices.

	Visual focus of attention indicator					
	Gini coefficient[c] $R^2 = 0.12$		Total fixation duration $R^2 = 0.04$		Fixation counts $R^2 = 0.15$	
	β	*p*	*β*	*p*	*β*	*p*
Direct effects on focus of attention						
Cortisol at 12:00–1:00 p.m.[a]	−0.08	0.555	0.03	0.793	0.00	0.997
Teaching practices[b]	**−0.34**	**0.001**	0.19	0.197	**0.39**	**<0.001**
Direct effect of cortisol on Teaching practices[b]	−0.05	0.727	−0.05	0.727	−0.05	0.727
Indirect effect of cortisol at 12:00–1:00 p.m. through Teaching practices	−0.02	0.730	−0.01	0.716	−0.02	0.722

β, standardized regression coefficient. *p*, value of *p*. [a]Cortisol concentrations are natural logarithm transformed and aggregated over two sampling days. Teaching practices- ratio of child-centered teaching practices compared with teacher-directed practices. [c]Distribution of teachers' visual focus of attention. Values in bold are significant.

TABLE 5 Regression model showing direct and indirect effects with variables such as psychological stress, visual focus of attention, and teaching practices.

	Visual focus of attention indicator					
	Gini coefficient[b] $R^2 = 0.12$		Total fixation duration $R^2 = 0.04$		Fixation counts $R^2 = 0.17$	
	β	*p*	β	*p*	*β*	*p*
Direct effects on focus of attention						
Psychological stress	−0.05	0.745	−0.01	0.988	0.13	0.320
Teaching practices[a]	−0.36	0.007	0.20	0.193	**0.46**	**<0.001**
Direct effect of stress on Teaching practices[a]	**−0.45**	**<0.001**	**−0.45**	**<0.001**	**−0.45**	**<0.001**
Indirect effect of psychological stress through Teaching practices	0.16	0.034	−0.09	0.236	−0.21	0.009

β, standardized regression coefficient. *p*, value of *p*. [a]Ratio of child-centered teaching practices compared with teacher-directed practices. [b]Distribution of teachers' visual focus of attention. Values in bold are significant.

4 Discussion

The aim of the present study was to investigate whether teachers' physiological stress, psychological stress, and teaching practices are associated with teachers' visual focus of attention and whether teachers' teaching practices mediate the effect of teachers' stress on their visual focus of attention. The results indicated that teachers' use of more child-centered teaching practices compared with teacher-directed ones was related to more individualized distribution of visual focus of attention and a greater number of fixations on students while teaching. In addition, the teacher's cortisol levels at 10:00 a.m. had a small, direct negative effect on the amount of total fixation duration on students. Furthermore, there was an indirect effect of teachers' psychological stress on teachers' visual focus of attention through their teaching practices.

First, the association between teachers' physiological and psychological stress and its relationship with teachers' visual focus of attention were investigated. The results showed that most of the measures of teachers' stress were not associated with the teachers' visual focus of attention. In this regard, our results do not support the hypothesis expecting that higher physiological and psychological stress is related to less individualized distribution of visual focus of attention and fewer fixations on students. This issue needs further investigation.

Second, the association between teachers' teaching practices and their visual focus of attention was investigated. The results showed that the more teachers used child-centered teaching practices compared with teacher-directed ones, the more they individualized the distribution of visual focus of attention among students and the greater the number of fixations on students. Teachers using child-centered teaching practices emphasize children's active participation, address their needs, interests, and initiatives, and actively scaffold their learning. In this regard, student-related factors in the classroom play an important role in guiding teachers' visual focus of attention during child-centered teaching practices. For instance, teachers give longer durations of visual focus of attention to students showing disruptive or interactive behavior (Goldberg et al., 2021), increased hand-raising behavior to participate in discussions (Kosel et al., 2023), and poor performance in basic academic skills (Chaudhuri et al., 2022b). Therefore, our results supported the hypothesis expecting that teachers using more child-centered practices compared with teacher-directed ones is related to more individualized distribution of visual focus of attention and more fixations on students.

Third, the mediating effect of teachers' teaching practices on the association between teachers' stress and their visual focus of attention was investigated. The results showed that teachers' physiological stress, in terms of their higher cortisol levels at 10:00 a.m., had a small effect on their shorter total fixation duration on students. However, there was an indirect effect of teachers' psychological stress on their visual focus of attention (distribution of visual attention and fixation counts) through their teaching practices. In other words, on a positive note, less psychological stress was related to more child-centered teaching practices, which in turn was related to more individualized distribution of visual attention and more fixations on students. It is plausible that employing more child-centered teaching practices would involve increased teachers' visual attention on students to provide individual support in order to encourage their academic and social skills development (Chaudhuri et al., 2022b). However, on a negative note, high psychological stress could be related to more teacher-centered teaching practices, which in turn could be related to less visual focus of attention on students. This result is supported by previous research stating that teachers experiencing high levels of psychological stress tend to show low quality of classroom organization, offer less emotional support (Penttinen et al., 2020), and use less instructional dialogue to support students' higher-order thinking skills (Bottiani et al., 2019). Therefore, our results are in line with the hypothesis that teachers' higher physiological and psychological stress is related to their visual focus of attention in the classroom and resulting in employing less child-centered teaching practices compared with teacher-directed practices.

4.1 Practical implications of the study

Teachers need to be aware of their stress levels as they are linked to the teaching practices they use in the classroom which in turn link to their visual focus of attention to the students. For example, mobile eye-tracking technology can be used during in-service trainings to generate teacher's awareness of their visual focus of attention toward students. Previous research has shown that while watching their own teaching videos, teachers reflected more critically on their own teaching practices and suggested alternative teaching strategies (Keller et al., 2021; Muhonen et al., 2023).

4.2 Limitations and future research directions

The present study has some limitations. First, this study was cross-sectional in design. In the future, a longitudinal approach throughout the academic year could provide in-depth insights into issues that affect teacher's work-related stress, teaching practices, and visual focus of attention. Second, teachers' visual focus of attention was measured for the first 20–25 min of a lesson, whereas teaching practices were assessed based on three full lessons. In the future, it could be beneficial to record entire lessons in order to study the variation in teachers' visual focus of attention during the beginning, middle, and end of a lesson. Previous research has shown that teachers' visual focus of attention varies based on their pedagogical intentions. For example, teachers focus their attention more on task-related targets when giving instruction than while reflecting on tasks (Maatta et al., 2021). Third, student-related factors and classroom composition were not considered in the present study. It is possible that there are more contextual factors, such as students' academic skill levels (Chaudhuri et al., 2022b), that influence the relationships between teachers' stress, teaching practices, and teachers' visual focus of attention. Also, we ran separate regression models for each of three outcomes and each of three stress measures due to the small sample size and the risk of multicollinearity. However, this increases the chance of Type I errors. In the future, multilevel modeling approaches need to be used to investigate other physiological measures related to teachers such as anxiety, and emotional arousal in association with teacher's visual focus of attention thereby allowing the examination of teachers' intraindividual differences. Furthermore, it would be beneficial to investigate whether teachers' physiological and psychological stress, teaching practices, and teachers' visual focus of attention vary based on teachers' work experience, particularly, between novice and expert teachers. Lastly, majority of the sample in this study consisted of females and there was little representation of the male gender ($N = 3$). This could be considered as a limitation in understanding how teaching related stress, teaching practices, and teacher visual focus of attention could vary across teachers' genders.

5 Conclusion

The current study makes a unique contribution to the existing literature by examining both physiological and psychological stress and their role in teachers' visual focus of attention in authentic classroom situations. The results indicate that teachers' psychological stress is related to their visual focus of attention through their teaching practices. Accordingly, teachers need to be encouraged to develop coping strategies in relation to their work-related stress since it effects their teaching practices and classroom behavior toward students.

Data availability statement

The datasets presented in this article are not readily available because cortisol and eye-tracking data cannot be shared publicly. Requests to access the datasets should be directed to the principal investigator of the project, M-KL (marja-kristiina.lerkkanen@jyu.fi).

Ethics statement

The studies involving humans were approved by University of Jyväskylä's ethical committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

SC: Conceptualization, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. A-LJ: Conceptualization, Formal analysis, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. EP: Conceptualization, Funding acquisition, Methodology, Resources, Writing – original draft, Writing – review & editing. M-KL: Conceptualization, Investigation, Methodology, Project administration, Resources, Writing – original draft, 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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Appendix 1

TABLE A1 Description of ECCOM child-centered and teacher-directed dimensions – subscales and scale items (based on Stipek and Byler, 2004; Lerkkanen et al., 2012).

Subscales and scale items	Dimensions	
	Child-Centered	*Teacher-Directed*
Management 1. Child responsibility	Children are allowed to take responsibility to the degree that they are able.	Children do not have opportunities to take responsibility (teacher control).
2. Management	Teacher has clear but somewhat flexible classroom rules and routines.	Teacher has clearly communicated expectations and classroom rules that are rigidly adhered to.
3. Choice of activities	Mixture of teacher and child choice.	Teacher makes most choices.
4. Discipline strategies	Conflict resolution is smooth; consequences are appropriate and apply equally.	Discipline is imposed without explanation or discussion; consequences are inconsistent.
Climate 5. Support for communication skills	Teacher encourages children to engage in conversation and elaborate on their thoughts.	Teacher does not encourage children to engage in conversation (teacher controlled conversation).
6. Support for interpersonal skills	Teacher provides opportunities for cooperative, small-group activities that promote peer interactions.	Teacher does not provide opportunities for children to develop interpersonal skills.
7. Student engagement	Teacher attempts to engage all children in ways that will improve their skills and understanding.	Teacher engages children in rote activities (e.g., rigid expectations about being engaged in work).
8. Individualization of learning activities	Teacher is attentive to children's individual skill level and adapts tasks accordingly.	Tasks are not flexible or adapted to children's individual needs (e.g., all do the same tasks).
Instruction 9. Learning standards	Teacher holds children accountable for attaining some individualized standard (assists and challenges children at their respective level).	Teacher rigidly holds children accountable for completing work and for attaining a universal standard (e.g., standards are rigid and invariable).
10. Coherence of instructional activities	There are connections between and within academic lessons (concepts/skills are embedded into a broader set of goals).	Academic lessons are distinct and disconnected (concepts/skills are presented as an isolated set of facts or skills to be learned).
11. Teaching concepts	Tasks and lessons are designed to teach identifiable concepts and develop understanding.	Tasks are designed to help children learn facts or procedures. Problem solving is constrained.
12. Instructional conversation	Teacher solicits children's questions, ideas, solutions, or interpretations around a clearly defined topic.	Teacher dominates instructional conversation; children's participation is limited.
13. Literacy instruction	The teacher provides a broad array of literacy experiences and instructional approaches.	The teacher's literacy instruction places a heavy emphasis on phonics and paper-pencil tasks.
14. Math instruction	Math instruction emphasizes developing understanding.	Math instruction emphasizes rote memorization, drill and practice.
15. Math assessment	Math assessment is on-going, includes a variety of formats, and is used to inform instruction.	Math assessment is formal, limited in variety, and focuses on right/wrong answers.

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The subject matters for the professional vision of classroom management: an exploratory study with biology and mathematics expert teachers

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Teacher professional vision of classroom management is one crucial aspect of teacher expertise that has so far been studied without considering the role of teachers' subjects. However, subject teaching is characterized by typical settings and activities that might require different classroom management strategies. This small-scale explorative study investigates whether twenty expert teachers from two secondary school subjects (biology and mathematics) differ in their professional vision of classroom management. Using video clips of two settings as stimuli, teachers' eye-tracking data and retrospective think-aloud data were recorded. Think-aloud data were investigated with quantitative content analysis and epistemic network analysis. Expert teachers' visual attention, their noticing of classroom management events, and their knowledge-based reasoning were compared for both groups. Results reveal subject-specific aspects of expert teachers' professional vision of classroom management in terms of events noticed and their reasoning about these events. Expert biology teachers were more concerned with suggesting alternative classroom management strategies, particularly strategies addressing aspects to consider when planning activities such as providing structure or preparing the classroom. In contrast, mathematics teachers were more evaluative in their analysis of events and focused more on behavioral management or ensuring students' engagement in the moment.

KEYWORDS

professional vision, teacher expertise, classroom management, subject teaching, think-aloud data, epistemic network analysis

1 Introduction

Teachers are constantly facing the challenging tasks of quickly noticing key elements of a teaching situation, coming up with adequate interpretations, and deciding on appropriate courses of action. These three skills of perception, interpretation, and decision-making have gained increasing attention in the last decade and have been studied under the terms of teacher professional vision, teacher noticing, or teacher situation-specific skills (Seidel and Stürmer, 2014; Stahnke et al., 2016; Santagata et al., 2021; König et al., 2022). There is evidence that supports the idea that teacher professional vision is an integral aspect of teacher competence as it mediates between teacher knowledge and instructional quality which in turn predicts student achievement (Blömeke et al., 2022). Accordingly, research revealed that novice and expert teachers differ in their professional vision thus indicating that professional vision is indeed one aspect of teacher expertise (e.g., Huang et al., 2021; Kosel et al., 2021; Wolff et al., 2021; Stahnke and Blömeke, 2021a). Hence, professional vision needs to be developed in teacher education by pre-service and beginning teachers. Insights into what characterizes experts' professional vision in contrast to novices could inform the design of learning opportunities that aim at fostering teacher professional vision.

Just as facets of teacher knowledge can be differentiated (e.g., pedagogical knowledge, content knowledge, and pedagogical content knowledge; Shulman, 1986) we can also refer to different foci of professional vision. A pronounced professional vision with respect to one aspect of teaching does not necessarily go hand in hand with a pronounced professional vision regarding other aspects of teaching (e.g., Steffensky et al., 2015). Thus, research often focuses on teacher professional vision of specific areas of teaching, for instance aspects of subject-specific teaching (e.g., Chan et al., 2020; Santagata et al., 2021) or pedagogical aspects such as classroom management (e.g., Grub et al., 2020; Gold et al., 2021; Wolff et al., 2021). The latter aspect of classroom management is one important dimension of instructional quality (Praetorius et al., 2018) that shows a high stability across a teacher's lessons (e.g., across one teacher's mathematics lessons; Praetorius et al., 2014). Prior studies revealed several differences between expert and novice teachers' professional vision of classroom management (TPVCM) with respect to their distribution of visual attention, their noticing of classroom management events, their interpretations of these events, and their decisions for appropriate subsequent classroom management strategies (e.g., Kosel et al., 2021; Shinoda et al., 2021; Wolff et al., 2021; Stahnke and Blömeke, 2021a,b).

Teacher professional vision is considered to be based on teachers' knowledge and teaching experience (Sherin and van Es, 2009; Seidel and Stürmer, 2014; Blömeke et al., 2015). While researchers have investigated the relationship between teachers' pedagogical knowledge, experience, and their TPVCM, relations between TPVCM and more subject-specific elements have been addressed far less. However, teaching in a particular subject is often characterized by specific classroom settings which are typical for that subject (e.g., student experiments in science classes, phases of independent and collaborative work on math problems or whole-class activities in music education or physical education). These different subject-related classroom settings often call for different classroom management strategies (Doyle, 2006; Kwok, 2021). Depending on the subjects that teachers teach, it can be assumed that they will build specific knowledge and make different experiences with respect to specific classroom settings that are particularly typical for the respective subjects. Consequently, their TPVCM might develop in a subject-specific way. Learning more about such subject-specific aspects of TPVCM can inform teacher education and professional development for different subject areas. This explorative study addresses this issue and aims to investigate how expert teachers of the two subjects of biology and mathematics differ in their TPVCM when observing two different instructional settings typical for these subjects (whole-group instruction and partner work). Thereby, their visual attention, noticing of classroom management events, and knowledge-based reasoning about noticed events are compared.

1.1 Expert teachers' professional vision of classroom management

The term *Professional Vision* was coined by Goodwin (1994) who used it to describe the "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (p. 606). While Goodwin (1994) referred to the domains of archeology and legal argumentations, Sherin and van Es (2009) applied the term to the domain of teaching, stating two processes that comprise teachers' professional vision: selective attention which is "how the teacher decides where to pay attention at a given moment" (p. 22) and knowledge-based reasoning as "the ways in which a teacher reasons about what is noticed based on his or her knowledge and understanding" (p. 22). Other researchers suggested different conceptualizations, either also using the term professional vision (Seidel and Stürmer, 2014), the term noticing (van Es and Sherin, 2002; Jacobs et al., 2010; van Es and Sherin, 2021) or other terms such as situation-specific skills (Blömeke et al., 2015; Kaiser et al., 2017). These conceptualizations have in common that they include what or how teachers perceive in classroom situations and how they interpret what they have perceived. In addition to teachers' perception and interpretation, their decision-making is also addressed in some conceptualizations (Blömeke et al., 2015; Kaiser et al., 2017). In this study, we use the term professional vision as it is more dominant in research with respect to classroom management. We understand professional vision as teachers' selective attention that enables them to notice relevant events and their knowledge-based reasoning about these noticed events which is comprised of their description and interpretation of events as well as their suggestions for courses of action (*cf.* Sherin and van Es, 2009; Seidel and Stürmer, 2014; Blömeke et al., 2015; Gippert et al., 2022). Furthermore, we specifically focus on teacher professional vision of classroom management (TPVCM) as one crucial dimension of instructional quality (Praetorius et al., 2018).

Classroom management can be defined as "the actions teachers take to create an environment that supports and facilitates both academic and social–emotional learning" (Evertson and Weinstein, 2006, p. 4). This broad definition of classroom management can include different aspects such as the management of student behavior in terms of discipline and order or the management of instruction by for instance giving lessons a clear structure, good time management, and choosing the right classroom setting (Kounin, 1970; Doyle, 2006). Furthermore, classroom management can address student motivation and emotions by fostering a positive climate and positive relationships (Wubbels et al., 2015). Classroom management strategies are either reactive, thus following student disengagement or disturbances, or preventive in the sense that they prevent unwanted student behavior and support student learning (Clunies-Ross et al., 2008). Novice teachers frame classroom management rather as an issue of order and discipline (Kaufman and Moss, 2010; Kwok, 2021). Thus, they also report to use reactive classroom strategies more frequently than preventive strategies (Reupert and Woodcock, 2010). Yet, in order to manage a classroom efficiently, teachers need various classroom management strategies that they need to use adaptively. This need for a broad repertoire of classroom management strategies becomes apparent with respect to the challenges that different classroom settings such as whole-group instruction, seat work or group work present (Doyle, 2006; Kwok, 2021).

Teacher professional vision is particularly important with respect to classroom management because teachers need to monitor student activity and student learning, draw conclusions, and act promptly (Doyle, 2006). We understand TPVCM as an important aspect of teacher expertise that is comprised of teachers' perception of classroom management events which includes teachers' distribution of attention and their noticing of relevant classroom management events, their knowledge-based reasoning about noticed classroom management events including their description and interpretation of events, and their generation of next, adaptive classroom management strategies (*cf.* Wolff et al., 2021; Stahnke and Blömeke, 2021a,b; Gippert et al., 2022).

These three aspects of TPVCM are supposed to be based on teachers' knowledge. In a recent theoretical model, Wolff et al. (2021) suggested that classroom management scripts are the knowledge structures that are the foundation for teachers' professional vision with respect to classroom management. Such scripts are comprised of the conditions that can enable the development of a typical classroom management event (e.g., conditions enabling student misbehavior), teachers' mental representation of the event, and consequences associated with the event (e.g., consequences for student learning). Expert teachers have developed more numerous and more elaborate knowledge structures such as scripts through deliberate practice than novice teachers (Berliner, 2001; Lachner et al., 2016; Wolff et al., 2021). These scripts are activated when a teacher experiences a familiar classroom situation and they influence teachers' perception, interpretation, and decision-making resulting in considerable differences between novices and experts (Borko et al., 2008; Wolff et al., 2021).

Recent research provided empirical evidence for the characteristics of expertise with respect to TPVCM. In order to notice potentially relevant classroom management events, teachers need to selectively attend to these events. In the context of classroom management, teachers' distribution of visual attention is particularly important since many students need to be monitored simultaneously and constantly (Grub et al., 2020). There is evidence that expert teachers distribute their visual attention more evenly than novices (van den Bogert et al., 2014; Huang et al., 2021; Kosel et al., 2023). Furthermore, experts show different visual scanpaths compared to novice teachers (McIntyre and Foulsham, 2018; Kosel et al., 2021). In particular, experts focus more on those areas of the classroom that show student and classroom activity than novice teachers (Wolff et al., 2016; Stahnke and Blömeke, 2021a). This is probably enabling them to notice off-task behavior with a higher accuracy than novices (Shinoda et al., 2021) and to notice more classroom management events than novices, especially in a more open partner work setting (Stahnke and Blömeke, 2021a). However, it should be noted that there are also several studies that found no effects of expertise or experience on TPVCM with respect to visual attention (Yamamoto and Imai-Matsumura, 2013; Grub et al., 2022) or the number of noticed events (van Driel et al., 2021). Reasons for these mixed findings may lie in the variance of study designs (e.g., on-action versus in-action designs or a focus on behavioral management versus a broader perspective on classroom management).

Regarding expert teachers' knowledge-based reasoning about noticed events, studies reported that experts make many interpretative statements when analyzing classroom situations (Wolff et al., 2017; Stahnke and Blömeke, 2021b). Moreover, experts' analyses are more focused on students and their learning (Wolff et al., 2017; Stahnke and Blömeke, 2021b). In addition, experts seem to take the context of a classroom event, i.e., the setting or classroom rules, into consideration (Stahnke and Blömeke, 2021b). Regarding the question of which aspects of classroom management expert teachers focus on in particular, there have been mixed results: Experts seem less concerned with aspects of discipline and order than novices (Wolff et al., 2017). Stahnke and Blömeke (2021b) could, however, not find this effect. In contrast, the expert teachers in their study referred often to (preventive) behavioral classroom management strategies in their analyses of classroom management events (Stahnke and Blömeke, 2021b). Following teachers' knowledge-based reasoning about classroom management events, they might need to decide on adaptive classroom management strategies. There is still little known about expertise with respect to this aspect of TPVCM. When expert teachers talk about video scenes they observed, they make more suggestions for alternative courses of action than novices (Wolff et al., 2017; Stahnke and Blömeke, 2021b). Experts' suggestions address either the observed teacher's management behavior or an adaption of the context, e.g., by choosing another setting or seating arrangement (Stahnke and Blömeke, 2021b).

As stated above, empirical results regarding expertise with respect to TPVCM are still limited and also contradictory to some extent. Furthermore, there appears to be considerable variance within expert teachers' TPVCM (van Driel et al., 2023). Additionally, recent research suggests that whether expertise effects can be observed also depends on the classroom setting. For whole-group instruction settings there were less differences observed between novices and experts than for more open classroom settings (Seidel et al., 2021; Stahnke and Blömeke, 2021a). At the same time, new methods for analyzing teacher professional vision are developed and used which can generate new insights. For instance, epistemic network analysis can reveal the epistemic knowledge networks underlying teacher professional vision (Farrell et al., 2022; van Driel et al., 2023).

1.2 The role of the teaching subject for teacher professional vision of classroom management

When we observe how different subjects are usually taught it becomes apparent that they do not only differ with respect to the content but also with respect to other characteristics. Different settings or methods are more useful for some contents than for others. For instance, partner work with students having conversations is particularly useful and therefore more often prevalent for collaborative problem-solving in mathematics education, while student experiments are a typical setting for science classes. Furthermore, subject teachers – especially in secondary schools – form a distinct subject subculture with different shared views, beliefs, and norms (Siskin, 1994; Grossmann and Stodolsky, 1995). Thus, subject departments are "sites where a distinct group of people come together, and together share in and reinforce the distinctive agreements on perspectives, rules, and norms which make up subject cultures and communities" (Siskin, 1994, p. 181).

Recalling Goodwin's (1994) definition of professional vision as being socially shared in specific communities, we suggest to consider subject subcultures to be such social groups with distinct interests that have shared ways of seeing (classroom management) events. Consequently, it is necessary to enrich the generic perspective that considers TPVCM to be more or less independent of the subject. Considering subject subcultures in research on TPVCM can reveal insights into the best ways to foster TPVCM for different subjects. There is evidence on the characteristics of subject subcultures that supports this argument: With respect to the characteristics of the subject subcultures focused in this study (mathematics and biology which is often taught in the context of science), Stodolsky and Grossman (1995) reported that in comparison to science teachers, mathematics teachers perceive their subject to have a more clearly defined content that is more sequential in nature and also more unchanging over time. Additionally, science teachers report to have more control and autonomy over the content that they teach than mathematics teachers. In terms of their daily work, mathematics teachers describe their work to be more routine than science teachers in the sense that they more often use similar teaching techniques or settings (Grossmann and Stodolsky, 1995; Stodolsky and Grossman, 1995).

Conceptualizations of instructional quality across subjects are generally similar with respect to classroom management. However, subject-specific aspects might need to be added or specified due to typical activities in a subject: For instance, ensuring student safety or the management of material or the room are aspects of classroom management that are particularly important for science teachers (Praetorius et al., 2020). Such aspects of the organization of the classroom or the learning environment are rarely considered in frameworks of instructional quality in mathematics education, which are often more focused on behavioral management (Mu et al., 2022). Similarly, the majority of pre-service teachers share the belief that the subject impacts how a classroom is managed (Kwok, 2021). According to the pre-service teachers in the study by Kwok (2021), this is due to four aspects: First, different contents are associated with different pedagogical activities that call for different structures and rules (i.e., different settings such as seat work, group work or hands-on activities such as experiments). Second, teachers believe that different contents are associated with different levels of student interest and ability which can prevent or enable student misbehavior. Third, the physical classroom in terms of class size, classroom space, and resources such as lab equipment influences what classroom strategies are needed. Finally, pre-service teachers believe that behavioral structures such as what control or authority looks like and what rules, procedures, and expectations are needed can differ depending on the content (Kwok, 2021). Consequently, pre-service teachers preferred their teacher educators or coaches to be from similar subject areas so that subject specificities can be addressed (Svajda-Hardy and Kwok, 2023).

Regarding TPVCM, there is little research investigating pedagogical aspects of teacher professional vision while also considering the role of different subjects. With respect to visual attention as a necessary condition for noticing events, Huang (2018) reported different fixation durations on students and materials during literacy lessons versus math lessons taught by the same teachers. Blomberg et al. (2011) compared the professional vision of pedagogical aspects such as teacher support in the case of pre-service teachers from two different domains (mathematics/science versus social sciences/humanities) and found that professional vision was both dependent on teachers' subject and the subject of the observed classroom scenes. The authors suggest that the pre-service teachers' subject-specific socialization in different subcultures causes such effects (Blomberg et al., 2011). Thus, although pre-service teachers are only exposed to this subject-specific socialization for a short period of time, their beliefs about classroom management and their professional vision support the notion that classroom management is impacted by the subject (Blomberg et al., 2011; Kwok, 2021). For experts who have worked within specific subject subcultures for many years, such subject-specific effects may be even more pronounced. Having experienced many lessons with typical classroom events in subject-specific classroom settings, it can be assumed that expert teachers develop more elaborate knowledge structures in the form of classroom management scripts for events typical for their subject (Wolff et al., 2021). Besides differences with respect to typical classroom management events, some subjects might also require more classroom management addressing student safety and the management of the room and the material (e.g., science; Praetorius et al., 2020). In contrast, other subjects may call for more short-term monitoring of student behavior and learning progress (e.g., mathematics; Kwok, 2021; Mu et al., 2022). If we accept that subjects differ with respect to typical classroom management events and typical demands on teachers' management, it stands to reason that even with respect to the generic aspect of classroom management, experts from different subjects will and should develop a different, subject-specific TPVCM.

2 The present study: exploring expert teachers' professional vision across subjects

Based on the subject-specific demands for teachers' classroom management and accordingly for the development of different classroom management scripts, expert teachers might differ in their TPVCM, depending on their teaching subject. This explorative study addresses this issue by investigating whether expert teachers from two different secondary school subjects (biology and mathematics) show differences in their TPVCM. More specifically, this study has three research questions focusing on three aspects of TPVCM:

> *RQ1*: Do biology and mathematics expert teachers differ with respect to their visual attention when observing classroom management scenes?
>
> *RQ2*: Do biology and mathematics expert teachers differ with respect to their noticing of classroom management events?
>
> *RQ3*: Do biology and mathematics expert teachers differ with respect to their knowledge-based reasoning about noticed classroom management events?

3 Materials and methods

3.1 Sample

For this study, we reanalyzed data from prior studies of nine biology and eleven mathematics expert teachers from lower secondary schools (for more details on the sample, materials and procedure *cf.* Stahnke and Blömeke, 2021a,b). None of the participating teachers taught both subjects (which would be a possible combination in the German context). The expert teachers had at least five years of teaching experience ($M_{bio} = 16.33$, $SD = 11.16$; $M_{math} = 19.91$, $SD = 10.92$) and had additional responsibilities and tasks, such as leading the subject department, or training pre-service teachers. All teachers reported to have experience in observing lessons of pre-service or beginning teachers as part of their tasks in teacher education. Also, at the time of data collection, all expert teachers but one were supervisors for pre-service or beginning teachers involving the regular observation of lessons and providing feedback.

We thus applied the two criteria comprising the first-gate for expert nomination as suggested by Palmer et al. (2005): at least five years of experience and teacher knowledge as reflected in teachers' degrees or certifications. Additionally, we also used teachers' responsibilities and tasks as indicators of an evaluation of their high performance by others. Since teachers mostly teach alone in the German context, peer nomination would neither be a usual nor a valid indicator of expertise. Student data linked to the individual teacher is not available and could thus not be used for expert identification.

3.2 Materials and procedure

We conducted a standardized experiment in which the participating expert teachers observed four authentic video clips of classroom scenes from biology and mathematics lessons in lower secondary schools (i.e., an on-action design). During the experiment, both teachers' eye-tracking and stimulated think-aloud data were recorded. The four video clips were selected via a multi-step procedure addressing visible classroom management events representing different aspects of classroom management, corresponding authenticity, and typicality as well as good audio and video quality (*cf.* Stahnke and Blömeke, 2021a).

For the purpose of this study, we will focus on two video clips. These two video clips were chosen because in both of them students and the teacher are visible and both clips show classroom settings which are particularly typical for the two subjects under investigation: The first clip shows a whole-group activity in a math lesson on fractions. The teacher guides the comparison of solutions to a math problem and students take turns with presenting their solution while the rest of the class should listen. The second clip shows a partner work activity in a biology lesson on osmosis. Students are working in pairs on an assignment while the teacher walks through the room (*cf.* Stahnke and Blömeke, 2021a,b; see Figure 1 for a screenshot of both clips). The classroom scenarios could be easily understood without specific content knowledge and were thus equally accessible to both teacher groups. Both classroom settings represented in the video clips are often used in biology and mathematics classes in the German context.

Participation took place at teachers' schools, in the university lab or at teachers' home and lasted between 45 and 75 minutes. The experiment started with consent forms and the Miles test for ocular dominance (Miles, 1929) followed by a test trial to familiarize teachers with the equipment and the stimulated think-aloud method. The main part of the study consisted of the same procedure for each of the video clips. The order of presentation of video clips was incompletely counterbalanced, i.e., participants were randomly assigned to different sequences of video clips while not all possible sixteen sequences were realized. Teachers viewed each video clip twice: First, their gaze was recorded and they were asked to press a button whenever they noticed an important classroom management event[1] (*cf.* van den Bogert et al., 2014). The video clip could not be paused. Then, the video clip was overlaid with teachers' prior gaze, viewed for a second time and paused at each time-stamped noticed event. Teachers were instructed to think aloud about the events noticed. Since concurrent think-aloud protocols can interfere with the cognitive processes taking place during complex tasks, we used a retrospective think-aloud protocol stimulating teachers' cognitive processes with their own gaze since such a procedure can support the validity of verbal data (van Gog et al., 2005; Hyrskykari et al., 2008; Prokop et al., 2020).

Eye movements were recorded with an SMI RED-m eye-tracker with 120 Hz and a 9-point calibration was performed before each video. A camera attached to the screen recorded teachers' gaze-stimulated think-aloud reports.

3.3 Data analysis

3.3.1 Eye-tracking data analysis

In order to answer research question 1 related to the participants' visual attention, teachers' eye movements were analyzed with regard to the percentage of gaze directed toward the students or the teacher in each of the video clips. For this purpose, areas of interest were defined in both video scenes for the teacher and for three student groups, i.e., students on the right, the middle, and the left of the classroom (see Figure 1 for screenshots and the areas of interest; for details on the eye-tracking data collection and analysis *cf.* Stahnke and Blömeke, 2021a). The visual attention of the two teacher groups (biology and mathematics teachers) was compared using non-parametric Mann–Whitney *U* tests.

1 Teachers received the following instruction before the first observation: "During the first observation we will record your eye movements. Please push this button every time you notice an event that is relevant for classroom management. By classroom management, we mean creating and maintaining a classroom environment that enables students to learn. During the second observation we will pause the video at each event. Please tell us what you thought when first seeing this event and why this event is relevant to you." The instruction before the second observation was "We will now see the video clip again and pause every time you noticed an event. Please tell us, what you thought when you first saw these events."

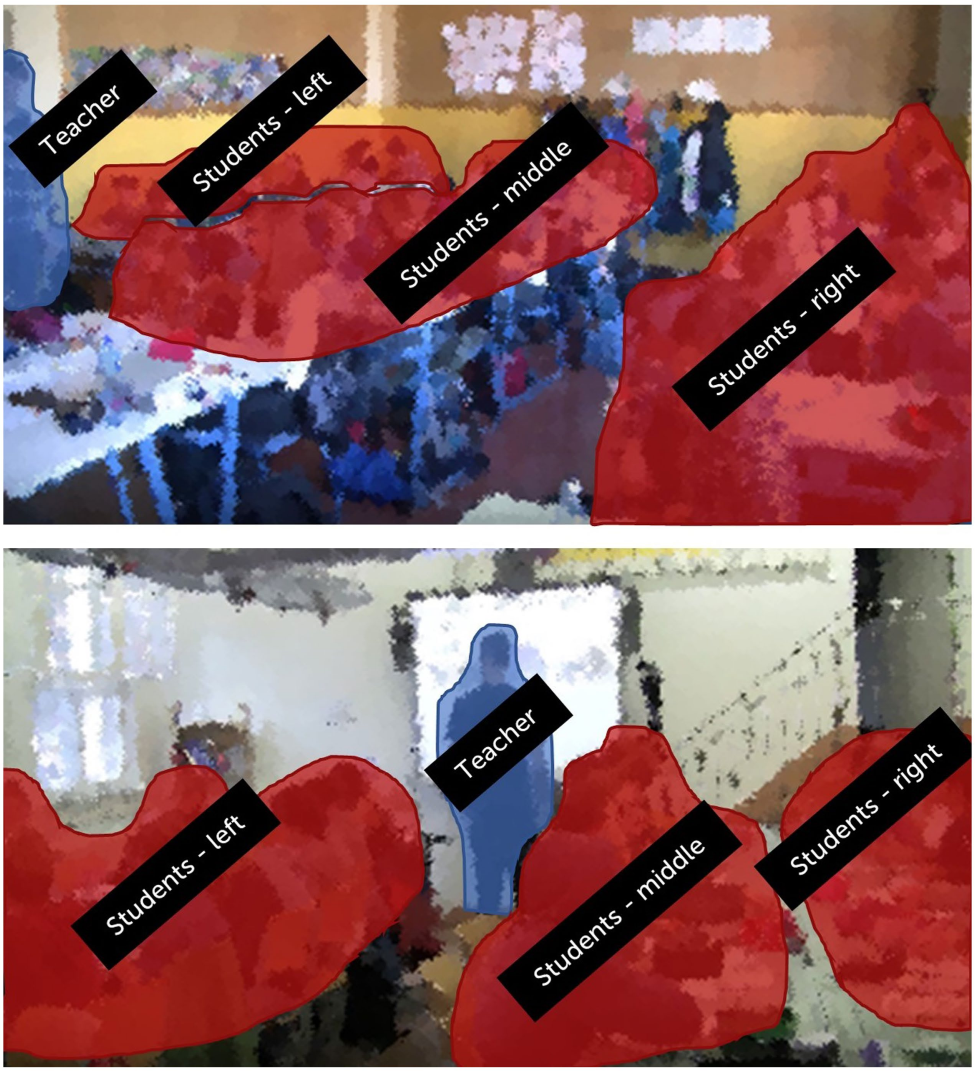

FIGURE 1
Areas of interest in the whole-group (top) and the partner work setting (bottom).

3.3.2 Content analysis of the think-aloud data

Think-aloud data were transcribed verbatim, segmented into idea units and coded for noticed events as well as for the content of teachers' verbal data. Expert teachers' think-aloud data consisted of 717 idea units for the whole-group setting and 688 idea units for the partner work setting.

Addressing research question 2 which focuses on the participants' noticing, we used a coding scheme to investigate whether participants noticed specific events based on their verbal data. For the whole group instruction, teachers' noticing of 26 events was coded; for the partner work, the noticing of 30 events was coded (for more details and the coding scheme *cf.* Stahnke and Blömeke, 2021a). Each classroom event was characterized as one of four event types: events focused on (1) student discipline, (2) student learning, (3) preventive classroom management strategies, or (4) reactive classroom management strategies. Since student learning events were rather rare, we aggregated student discipline and student learning events into one category. We then compared both groups of teachers regarding their number of noticed events of different types using Mann–Whitney *U* tests.

Research question 3 relates to the expert teachers' knowledge-based reasoning and was answered using content analysis and epistemic network analysis (see next section). The coding procedure for teachers' think-aloud data involved two steps: Each idea unit received one code indicating their level of knowledge-based reasoning (i.e., a perception code, an interpretation code, or a decision-making code). Then, each idea unit was coded with one code for the focus of knowledge-based reasoning (i.e., a student code, a teacher code, or a context code). There were multiple sub-codes with respect to both teachers' level and focus of reasoning: Sub-codes for the interpretation code included among others inferences, negative evaluations, or positive evaluations; sub-codes for the student code included student learning or student negative behavior; sub-codes for the teacher code were, for instance, the management of misbehavior, monitoring, or the flow of the lesson (for the detailed coding scheme *cf.* Stahnke and Blömeke, 2021b). While the content analysis was based on the general

TABLE 1 Example of coded data from one expert teacher.

Time stamp	Idea unit	Code for level (general code/subcode)	Code for focus (general code/ subcode)
1	1: First of all, I like that there is a clear task on the smart board with a time limit.	Interpretation/positive evaluation	Teacher/control of the lesson flow
	2: It is very visible what everybody has to do.	Perception/description	Teacher/control of lesson flow
	3: And it's good that he is not standing somewhere on the side, but tries to actively monitor the students' progress.	Interpretation/positive evaluation	Teacher/monitoring
2	1: It seems that the teacher decided not to react to his behavior yet [student puts on a hat].	Interpretation/inference	Teacher/management of misbehavior
	2: He [the teacher] first observed and waited what he [the student] will do next.	Perception/description	Teacher/monitoring
	3: This can be a sensible decision if you do not want to escalate the situation.	Interpretation/positive evaluation	Teacher/management of misbehavior
3	1: This seating arrangement would annoy me – I would change it.	Decision-making/specific suggestion	Context/classroom
	2: They [the students] are supposed to work together, but the seating arrangement does not work with this setting.	Interpretation/negative evaluation	Context/classroom
	3: That's why they are getting so loud.	Interpretation/negative evaluation	Students/negative behavior
	4: But maybe he [the teacher] cannot change this [seating arrangement] in this room with these tables.	Interpretation/contextualizing	Context/classroom

This is only an excerpt of all idea units from this teacher.

codes, general codes and sub-codes were analyzed in the epistemic network analysis (ENA). Table 1 shows an example for the coded data.

The first author coded all verbal reports. A second independent coder coded 10% of the material. Intercoder reliability was moderate to strong (Cohen's kappa for the coding of events noticed: $\kappa_{wg} = 0.81$ for the whole-group setting and $\kappa_{pw} = 0.87$ for the partner work setting; Cohen's kappa for the coding of knowledge-based reasoning: $\kappa_{wg} = 0.77$ for the whole-group setting and $\kappa_{pw} = 0.80$ for the partner work setting).

The coded data was then analyzed using a quantitative approach: To control for the different number of classroom management events noticed among teachers, we analyzed proportions of idea units assigned to a code instead of frequencies. Thereby, teachers' knowledge-based reasoning can be characterized irrespective of the length of their utterances or the number of events they noticed. Accordingly, a proportion of 0.40 of idea units coded with "student" would indicate that 40% of all idea units of one teacher were coded as focused on students, irrespective of the total number of idea units. Proportion of codes were compared between both groups with non-parametric Mann–Whitney *U* tests.

3.3.3 Epistemic network analysis of the think-aloud data

In order to complement the content analysis and to allow for a more extended insight into expertise with respect to the cognitive structures representing TPVCM, we conducted an epistemic network analysis (ENA). Such an analysis can complement findings of the quantitative content analysis and thus answer research question 3 (which focusses on expert teachers' knowledge-based reasoning) in a more comprehensive way. ENA is a method that can identify and also quantify connections among codes by creating network models; these network models can be represented as network graphs (Shaffer et al., 2016; Shaffer and Ruis, 2017). The size of nodes in such network graphs represent the relative frequencies of codes while the thickness of lines connecting codes represents how often codes co-occur within stanzas (i.e., segments of coded data of a predefined length that are assumed to contain related codes). Such epistemic networks can generate insights into the structure of connections between cognitive elements such as knowledge or skills among a community of practice (Shaffer, 2004) and have recently also been used in teacher professional vision research (Farrell et al., 2022; van Driel et al., 2023).

The basis of the ENA were the coded think-aloud data (see descriptions of codes for the level and focus of knowledge-based reasoning above). We used the ENA Web Tool (Marquart et al., 2018) which identifies network models representing the co-occurrence of codes within stanzas. In our study, we treated participants as units and all idea units following one individual time-stamp were treated as stanzas using a whole-conversation setting (i.e., we analyzed the co-occurrence of codes within all utterances made when the video was paused after teachers pushed a button to indicate an event noticed). Thereby, the co-occurrence of codes within teachers' think-aloud data referring to individual time stamps can be modeled, which enables to go beyond analyzing aggregated data of code frequencies or proportions (Csanadi et al., 2018). In order to avoid over-fitting in our small sample with many sub-codes, we dropped very infrequent sub-codes or used main codes instead. Thus, fifteen (sub)codes were the basis of the ENA.

ENA identifies an epistemic network for each participant and positions nodes in exactly the same position in the network projection space for each network, thus making it possible to summarize networks for groups of teachers and also to compare networks (Shaffer et al., 2016; Shaffer and Ruis, 2017). For this purpose, we generated subtraction networks that visualize the differences between the average networks of both groups of expert teachers for each classroom setting. Networks of teacher groups were compared using Mann–Whitney U tests and goodness of fit was analyzed.

4 Results

4.1 Expert teachers' visual attention when observing the classroom scenes

Descriptive data on the participants' visual attention is presented in Table 2. In the whole-group setting, both groups of teachers showed the lowest gaze proportions for the teacher and the student group on the left. Biology teachers spent most time looking at the students in the middle or the right side of the classroom. In contrast, mathematics teachers looked nearly twice as long at the middle student group than at the right student group. In the partner work setting, biology teachers paid most attention to the left and the middle student group while mathematics teachers were additionally paying a considerable amount of attention on the teacher in the scene (nearly one fifth of the time). Mann–Whitney U tests revealed only a few significant differences between the two teacher groups: In the whole-group setting, biology teachers paid more attention to one student group on the right side of the room ($U = 14.00$, $p = 0.006$, $d = 1.51$); in the partner work setting, mathematics teachers spent more time looking at the classroom teacher ($U = 76.00$, $p = 0.046$, $d = 1.01$). Thus, overall there are some differences between both subjects suggesting that mathematics expert teachers paid more attention to the classroom teacher and biology teachers focused more on certain student groups.

4.2 Expert teachers' noticing of classroom management events

Overall, both groups of teachers noticed a similar number of events in the whole-group setting ($M_{bio} = 6.22$, $SD_{bio} = 2.82$; $M_{ma} = 7.91$, $SD_{ma} = 3.21$) and partner work setting ($M_{bio} = 9.78$, $SD_{bio} = 3.35$; $M_{ma} = 9.36$, $SD_{ma} = 3.07$) with high variance in both groups and for both settings. In the whole-group setting, both groups of teachers noticed a similar number of events focused on students ($M_{bio} = 2.22$, $SD_{bio} = 0.83$; $M_{ma} = 2.64$, $SD_{ma} = 1.50$) and preventive classroom management strategies ($M_{bio} = 2.11$, $SD_{bio} = 1.54$; $M_{ma} = 1.82$, $SD_{ma} = 1.89$). With respect to reactive classroom management strategies, mathematics teachers noticed more events ($M_{bio} = 1.89$, $SD_{bio} = 1.76$; $M_{ma} = 3.45$, $SD_{ma} = 2.07$). However, this difference did not reach the level of significance ($U = 71.50$, $p = 0.095$, $d = 0.81$). In the partner work setting, biology and mathematics teachers did not differ significantly with respect to the number of student-related events ($M_{bio} = 4.00$, $SD_{bio} = 1.12$; $M_{ma} = 3.73$, $SD_{ma} = 1.95$), events addressing reactive classroom management strategies ($M_{bio} = 2.67$, $SD_{bio} = 1.41$; $M_{ma} = 2.91$, $SD_{ma} = 1.14$), or preventive classroom management strategies ($M_{bio} = 3.11$, $SD_{bio} = 2.09$; $M_{ma} = 2.73$, $SD_{ma} = 1.42$).

An overview of specific classroom management events noticed by biology and mathematics teachers is given in Table 3 for the whole-group setting and Table 4 for the partner work setting. In order to focus on the most important events, only events that were noticed by at least five teachers, i.e., a quarter of teachers, are further considered. Overall, biology and mathematics teachers' noticing of specific events is rather similar with a few events that seem to have drawn the attention of one group of teachers more strongly than the other group. In the whole-group instruction setting, the majority of mathematics teachers considered the following events as noteworthy: the classroom teacher's calling of students by name as a sign to be quiet, the teacher repeatedly asking the students to be quiet, and the teacher pulling through to the break (i.e., reactive classroom management strategies). In contrast, these events were only noticed by up to a third of the biology teachers. Conversely, the group of biology teachers noticed more often that a student raising her hand is being ignored and that the teacher's position in the classroom is disadvantageous for his classroom management (i.e., preventive classroom management strategies). Also, in the partner work setting, a few events seem to be of particular interest for the group of biology teachers: They noticed more often how two students quarrel behind the teacher's back who is then not able to see them (i.e., a student discipline event and a preventive strategy event). However, mathematics teachers addressed more often how the teacher in the scene reacts to students wearing hats or hoodies (i.e., a reactive strategy). Thus, both groups notice overall a similar number of events. With respect to specific events, biology teachers notice preventive strategies and students discipline events more often. In contrast, mathematics teachers notice reactive strategies more often.

4.3 Expert teachers' knowledge-based reasoning

With respect to the expert teachers' knowledge-based reasoning, we first compared their proportions of idea units assigned to the respective codes. We then investigated how their knowledge-based

TABLE 2 Biology and mathematics expert teachers' proportion of gaze directed to student groups or the teachers in the whole-group and partner work setting.

	Whole-group instruction		Partner work	
	Biology teachers ($n = 9$)	Mathematics teachers ($n = 11$)	Biology teachers ($n = 9$)	Mathematics teachers ($n = 11$)
Teacher	$M = 4.23$; $SD = 4.58$	$M = 8.83$;$SD = 7.45$	$M = 11.11$; $SD = 8.16$*	$M = 19.15$; $SD = 11.16$*
Students – left	$M = 8.92$; $SD = 2.50$	$M = 7.76$; $SD = 4.38$	$M = 27.18$; $SD = 8.34$	$M = 21.80$; $SD = 8.87$
Students – middle	$M = 27.66$; $SD = 9.13$	$M = 32.86$; $SD = 6.43$	$M = 33.01$; $SD = 4.80$	$M = 30.32$; $SD = 5.44$
Students – right	$M = 29.35$; $SD = 8.61$**	$M = 17.51$; $SD = 7.96$**	$M = 8.45$; $SD = 5.13$	$M = 7.55$; $SD = 4.06$

*$p < 0.05$, **$p < 0.01$.

TABLE 3 Percentage of biology and mathematics expert teachers that noticed classroom management events in the whole-group setting.

Classroom management events	Biology teachers	Mathematics teachers
Student discipline and student learning events		
Student lingers and clowns around after his presentation	44.44	54.55
Students do not listen to the student presenting her solution	33.33	45.45
Whole class is unruly and loud	66.67	54.55
Individual students are disengaged and misbehaving	55.56	45.45
Individual students are engaged and attentive	11.11	36.36
Reactive classroom management strategies		
Teacher calls students by their names and urges them to be quiet	33.33	72.73
Teacher asks students to pull through because the break is close	66.67	45.45
Teacher asks students to be quiet	22.22	63.64
Teacher asks students to pull through again because the break is close	33.33	63.64
Teacher asks students louder and more urgently to be quiet	22.22	36.36
Preventive classroom management strategies		
Student is raising her hand and the teacher ignores her	55.56	36.36
Teacher's position in the room	44.44	18.18
Teacher's posture and presence	22.22	27.27

(Sub)categories of classroom management events noticed based on Stahnke and Blömeke (2021a). The table presents results for classroom management events that were noticed by at least five expert teachers.

reasoning can be characterized by epistemic networks, as described above.

Looking at the level of knowledge-based reasoning and the focus separately, biology teachers' verbal analyses of the whole-group instruction setting proposed tentatively more alternative courses of action ($M_{bio} = 21.68$, $SD_{bio} = 18.44$; $M_{ma} = 7.57$, $SD_{ma} = 10.98$; $U = 24.00$, $p = 0.056$, $d = 0.96$) and addressed the context of the classroom management event more often (e.g., the chosen seating arrangements or instructional setting) than mathematics teachers' analyses ($M_{bio} = 12.39$, $SD_{bio} = 11.64$; $M_{ma} = 3.25$, $SD_{ma} = 3.70$; $U = 23.50$, $p = 0.055$, $d = 0.99$). No such differences were found for the partner work setting. Table 5 shows the proportion of idea units reflecting both the level and content of teachers' knowledge-based reasoning for both settings. In both settings, biology expert teachers' think-aloud data contain more suggestions for alternative teacher behavior, whereas mathematics teachers describe to a larger extent how they perceive the teachers' classroom management behavior in the whole-group setting. Mathematics teachers also state more interpretive comments about the students in the partner work setting. Overall, the proportions of idea units suggest that expertise with respect to knowledge-based reasoning is more linked to making suggestions for alternative strategies and addressing the context for biology teachers, and more linked to descriptions of the teacher's behavior and interpretation of student actions for mathematics teachers.

To complement our content analysis, we used ENA in order to investigate the connection between codes and to make the structure of teachers' epistemic networks visible. The subtraction network of biology and mathematics teachers is presented in Figure 2 for the whole-group setting and in Figure 3 for the partner work setting (the primary networks for each group are presented in the Appendix). Green lines show a stronger connection between nodes (i.e., codes) for biology teachers; red lines show stronger connections for mathematics teachers. The mean positions of biology and mathematics teachers' networks on the x axis differed significantly for both settings (whole-group instruction: $U = 4.00$, $p < 0.001$, $r = 0.92$; partner work: $U = 1.00$, $p = < 0.001$, $r = 0.98$). Goodness of fit was very high (whole-group instruction: 0.978 for the x axis and 0.976 for the y axis; partner work: 0.987 for the x axis and 0.998 for the y axis). Nodes near the middle of the network indicate less variance while nodes with greater distance indicate that teachers differ with respect to the connections with these nodes.

The subtraction network for the whole-group instruction format shows a clear pattern for mathematics teachers' epistemic networks with stronger connections on the right side of the network for the code pairs *descriptions of the events/the teacher's management of misbehavior* and *management of misbehavior/negative evaluations* of the observed classroom management. In contrast, the subtraction network for biology teachers shows many stronger connections on the left side of the network. Codes that are more strongly connected for biology experts include in particular connections with the *context* (i.e., the setting or seating arrangements) and connections with *suggestions for alternative courses of action*. Furthermore, *students' negative behavior* and *student learning* are more interconnected with other codes. Additionally, biology teachers' epistemic networks can be characterized by more links to codes indicating that the teachers get themselves *oriented* in the scene or lesson as well as statements that *contextualize* their own statements with respect to the conditions and resources available.

In the partner work setting, a similar pattern emerges from the subtraction network: Mathematics teachers' epistemic networks show stronger connections for the code pairs *perception/*

TABLE 4 Percentage of biology and mathematics expert teachers that noticed classroom management events in the partner work setting.

Classroom management events	Biology teachers	Mathematics teachers
Student discipline and student learning events		
Two students fool around and quarrel	77.78	45.45
Student is wearing a hood which is against rules	33.33	36.36
Student seems to be unmotivated and sad	22.22	45.45
Student puts on a hat which is against rules	88.88	72.73
Student takes off hat	22.22	36.36
Whole class is unruly and loud	77.77	63.64
Reactive classroom management strategies		
Teacher does not react to hooded student (yet)	11.11	36.36
Teacher is hunched over and talking to hooded student	22.22	54.55
Teacher does not react to student with hat (yet)	77.78	54.55
Teacher pulls student's hat	55.56	100.00
Preventive classroom management strategies		
Teacher could not see students fighting	55.56	0.00
Teacher goes through rows and monitors students	44.44	45.45
Group work or partner work (setting of instruction)	44.44	63.64
Teacher's posture and presence	22.22	36.36
Seating arrangements	33.33	36.36
Rule of no jackets or headwear in science classrooms	33.33	45.45

(Sub)categories of classroom management events noticed based on Stahnke and Blömeke (2021a). The table presents results for classroom management events that were noticed by at least five expert teachers.

TABLE 5 Biology and mathematics teachers' proportions of idea units reflecting the focus and the level of teachers' knowledge-based reasoning.

	Whole-group instruction		Partner work	
	Biology teachers	Mathematics teacher	Biology teachers	Mathematics teacher
Students in focus				
Perception	$M = 24.44$; $SD = 9.88$	$M = 22.74$; $SD = 16.40$	$M = 27.41$; $SD = 12.76$	$M = 21.46$; $SD = 17.00$
Interpretation	$M = 8.67$; $SD = 5.00$	$M = 10.00$; $SD = 7.23$	$M = 5.16$; $SD = 4.05^{+}$	$M = 10.35$; $SD = 7.16^{+}$
Decision-making	$M = 2.82$; $SD = 4.85$	$M = 0.88$; $SD = 2.15$	$M = 1.57$; $SD = 2.02$	$M = 0.87$; $SD = 1.53$
Teacher in focus				
Perception	$M = 9.80$; $SD = 11.25^{*}$	$M = 25.59$; $SD = 21.85^{*}$	$M = 8.11$; $SD = 6.77$	$M = 13.86$; $SD = 12.32$
Interpretation	$M = 26.23$; $SD = 19.55$	$M = 31.16$; $SD = 12.89$	$M = 26.71$; $SD = 13.10$	$M = 31.31$; $SD = 12.24$
Decision-making	$M = 15.65$; $SD = 11.50^{+}$	$M = 6.38$; $SD = 8.88^{+}$	$M = 14.38$; $SD = 13.22^{+}$	$M = 5.52$; $SD = 4.91^{+}$
Context in focus				
Perception	$M = 2.47$; $SD = 3.12$	$M = 0.44$; $SD = 10.49$	$M = 0.44$; $SD = 0.90$	$M = 1.61$; $SD = 2.89$
Interpretation	$M = 6.71$; $SD = 7.37$	$M = 2.50$; $SD = 3.26$	$M = 13.85$; $SD = 6.18$	$M = 11.43$; $SD = 8.38$
Decision-making	$M = 3.21$; $SD = 5.79$	$M = 0.31$; $SD = 0.68$	$M = 2.37$; $SD = 2.75$	$M = 3.58$; $SD = 5.53$

$^{+}p < 0.10$; $^{*}p < 0.05$.

positive evaluations, *positive evaluation/the teacher's management of misbehavior* as well as *positive evaluation/monitoring*. Biology teachers' networks show many stronger links from *students' negative behavior* and *suggestions for alternative strategies* to the *context*, teachers' *perception* and also the classroom teacher's *monitoring*. Again, links to *orienting* or *contextualizing* statements are more characteristic for biology teachers' epistemic networks.

In summary, the ENA results confirm and also extent the results of the content analysis: Biology expert teachers' knowledge-based reasoning was characterized by addressing alternative strategies for teacher behavior or the context as well as aspects of students' negative behavior and learning. In contrast, mathematics teachers' knowledge-based reasoning can be characterized as more evaluative and more focused on the teachers' management of misbehavior.

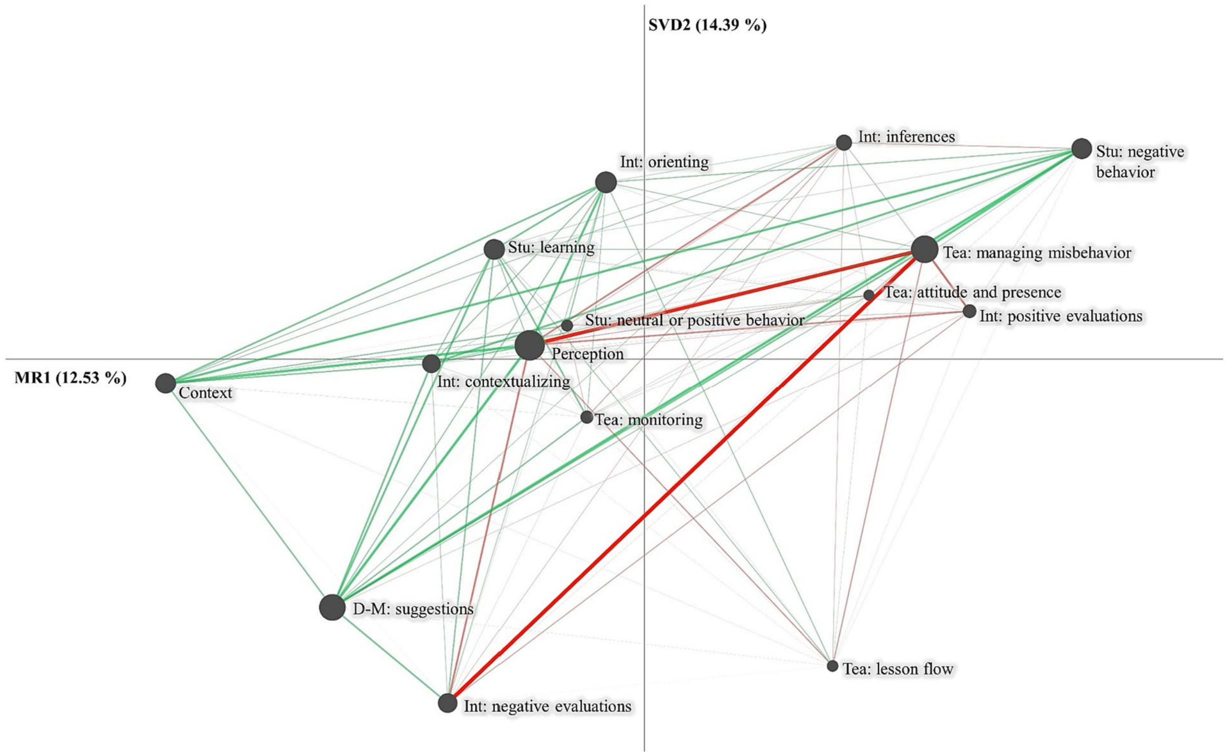

FIGURE 2
Epistemic subtraction networks of differences between biology expert teachers' (green) and mathematics expert teachers' (red) TPVCM for the whole-group instruction setting. Black dots indicate nodes: bigger dots indicate more frequent codes; colored lines indicate differences of the strengths of connections between both groups: red lines show stronger connections for mathematics teachers, green lines stronger connections for biology teachers, thicker lines show more frequent connections. Int, interpretation; D-M, decision-making; Stu, students; Tea, teacher.

5 Discussion and conclusions

5.1 Expert teachers' visual attention, noticing, and knowledge-based reasoning

This explorative study compared three aspects of 20 biology and mathematics expert teachers' professional vision of classroom management (TPVCM). Thereby, three research questions addressing teachers' visual attention, their noticing of classroom management events, and their knowledge-based reasoning were compared with eye tracking analysis, quantitative content analysis, and epistemic network analysis (ENA). With regard to the first research question, teachers' visual attention differed with respect to only two aspects: In the whole-group setting, biology teachers paid more attention to one student group on the right side of the room; in the partner work setting, mathematics teachers spent more time looking at the classroom teacher. Concerning the second research question, content analysis revealed some characteristics of biology and mathematics expert teachers that suggest that the participating biology teachers seem to be more concerned with preventive classroom management events while some reactive classroom management events were more frequently noticed by the mathematics teachers. However, overall teachers of both groups were rather similar in their noticing of events. With respect to the third research question, content analysis and ENA revealed that biology and mathematics expert teachers showed different characteristics in their knowledge-based reasoning about the classroom management events they noticed. Biology expert teachers seem to be more concerned with aspects of the context of the classroom event as well as with suggestion for alternative classroom management strategies. In contrast, mathematics teachers' knowledge-based reasoning can be characterized by a stronger connection between descriptive comments, the teacher's management of misbehavior and evaluations of the teacher's behavior. Overall it can be stated that expert teachers teaching the same subject show similar TPVCM for both settings.

The results for the first research question reveal only few subject effects on TPVCM in terms of visual attention. Overall, expert teachers spent most time looking at the students in the observed classroom scenes which is in line with characteristics of expertise found in expert-novice studies (e.g., Grub et al., 2020). Consequently, teacher expertise with regard to selective attention, thus their monitoring of a classroom, might be more general than subject-specific. This could be based on similar requirements for teachers' visual attention in both subjects. In response, both biology and mathematics teachers might have developed similar TPVCM with respect to selective attention that enables them to notice classroom management events quickly by paying attention to those areas where potentially relevant events can take place. The involved top-down processes might drive both biology and mathematics experts' gaze to similar areas (Grub et al., 2020; Seidel et al., 2021; Stahnke and Blömeke, 2021a; Gegenfurtner et al., 2022). Beyond the similarities of both groups of teachers, our results suggest several subject-specific tendencies: Biology teachers tend to focus more on the students in one

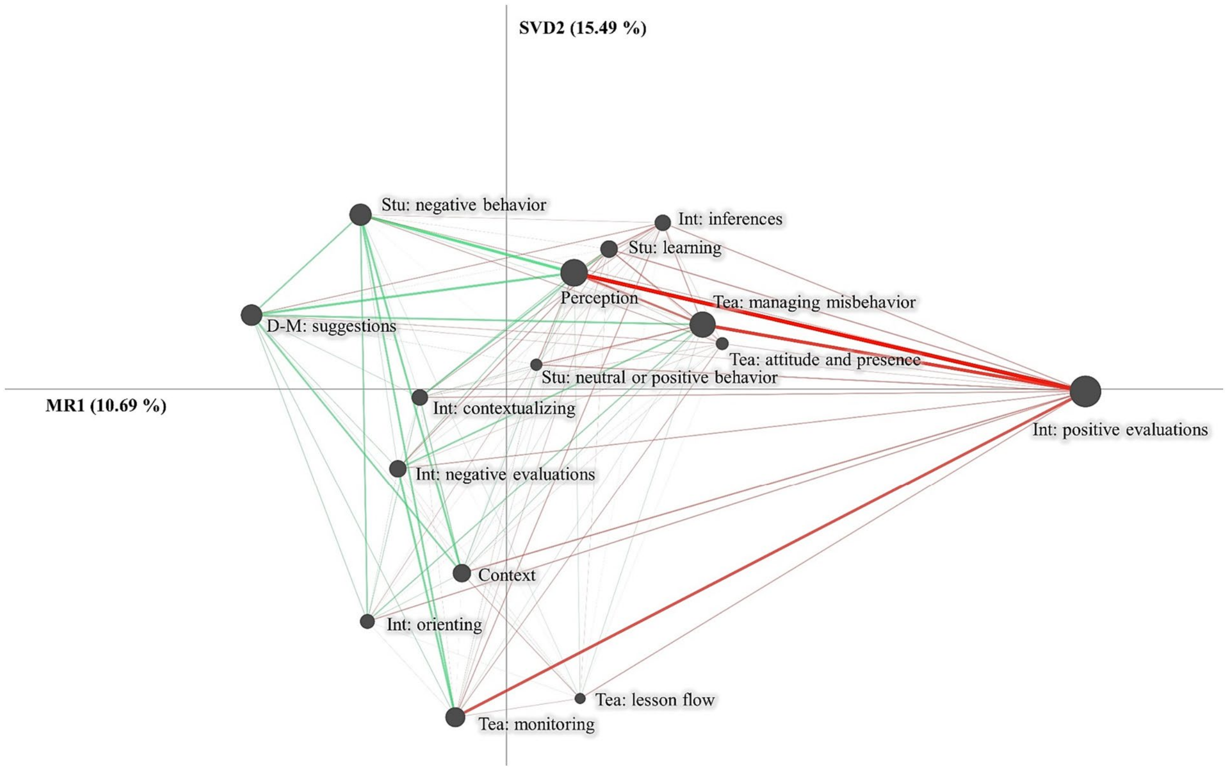

FIGURE 3
Epistemic subtraction networks of differences between biology expert teachers' (green) and mathematics expert teachers' (red) TPVCM for the partner work setting. Black dots indicate nodes, bigger dots indicate more frequent codes; colored lines indicate differences of the strengths of connections between both groups: red lines show stronger connections for mathematics teachers, green lines stronger connections for biology teachers, thicker lines show more frequent connections. Int, interpretation; D-M, decision-making; Stu, students; Tea, teacher'.

setting, while mathematics teachers are more focused on the teacher in that setting. Such a pattern might be driven by the need for more preventive management that also addressed the context for biology teachers (as observed in their noticing and knowledge-based reasoning). Markedly, the student group that biology teachers significantly paid more attention to showed a student raising her hand and being ignored, which was one of the events that was more often noticed by biology teachers. In comparison, mathematics teachers' focusing more on reactive strategies and the teacher's in-the-moment management (as indicated by their noticing and knowledge-based reasoning) might have driven their gaze more toward the teacher. Thus, while both groups of experts focus on areas that are relevant across subjects, *which* events are relevant to subject-specific classroom management might differ for the two subjects (*cf.* Huang, 2018). However, our findings should be interpreted with caution and need to be replicated with larger samples. Comparing expert teachers from other subjects with different affordances for classroom management (e.g., subjects that afford a lot of communication such as language arts or subjects that are characterized by whole-class activities such as music or physical education) might also be a promising approach.

Regarding the second research question, we found some effects of the subject on teachers' noticing of classroom management events. Since teachers' gaze was rather similar and they consequently had similar chances to observe events, the results possibly also indicate their judgment of what constitutes a note-worthy event. Since the expert teachers in our study are all supervisors of pre-service or beginning teachers and for this reason very likely familiar with criteria of instructional quality for their subject, the results could indicate which aspects of classroom management different subject cultures emphasize. While both groups of teachers agree on many classroom management events, the biology teachers seem to focus more on preventive aspects of classroom management. In contrast, the mathematics teachers are more concerned with reactive management of misbehavior. These findings can be interpreted against the background of subject-specific demands for classroom management: For biology classes, preventive strategies that ensure student safety during experiments and provide structure for transitions between different settings might be particularly important (Doyle, 2006; Kwok, 2021). This is reflected in instructional quality frameworks for biology instruction that also address ensuring student safety (Praetorius et al., 2020). The subject of mathematics is often perceived as more sequential by teachers (Stodolsky and Grossman, 1995). Thus, continuous behavioral management in terms of monitoring student behavior and engagement might be particularly important for mathematics teachers. Such an emphasis on behavioral management can also be found in instructional quality frameworks for mathematic education (Mu et al., 2022). Further research is needed that replicates and complements our findings by investigating teachers from other subject areas and stimuli that display settings that vary with respect to how typical they are for the respective subjects. Investigating how teachers' beliefs about classroom management in their subject area and their TPVCM relate, could generate further insights into how subject-specific TPVCM is and what roles subject subcultures play. Furthermore, taking a subject-specific perspective could be a promising direction for providing insights that can inform teacher education for different subjects. Such a subject-specific consideration has recently been proposed for classroom management coaching of pre-service teachers (Svajda-Hardy and Kwok, 2023).

With respect to the last research question, our analyses revealed new characteristics of expert biology and mathematics teachers' knowledge-based reasoning. Biology teachers made more suggestions for alternative courses of action and talked more about the context (i.e., the classroom, the seating arrangements or the setting) than mathematics teachers. Similarly, biology teachers' epistemic networks showed stronger connections to the context of the classroom scene and alternative classroom management strategies. Thus, they particularly addressed aspects of managing the classroom and material which are important criteria of high-quality instruction in biology (Praetorius et al., 2020). Biology teachers framed classroom management more in terms of (alternative) strategies for preparing a lesson and establishing structure. Such strategies might be particularly important when students are involved in hands-on activities such as experiments in a physical space that calls for additional rules such as a lab (Praetorius et al., 2020; Kwok, 2021). In contrast, mathematics teachers' epistemic networks were more focused on teacher's specific management behavior in terms of managing misbehavior or monitoring student work. Additionally, their knowledge-based reasoning was more evaluative of the teacher's shown management behavior. Hence, mathematics teachers framed classroom management as an in-the-moment task where the teachers' role is to address or prevent behavioral problems. Such strategies can be especially helpful when teachers need to manage more controlled settings where they can monitor how the class is doing in shorter intervals and with less safety risk than in a science lab.

Overall, these results – although based on an exploratory study with a small sample – suggest that there are subject-specific aspects of expertise with respect to TPVCM. Think-aloud data provided relevant insights in this regard that eye-tracking data alone could not have revealed. The subject-specific differences are probably adaptive to the different challenges that subject teaching can place on teachers' classroom management in terms of typical activities, student engagement, classroom features, or behavioral structures needed (Kwok, 2021). In the context of instructional quality research, these subject-specific demands have been addressed when subject-specific criteria for generic dimensions of instructional quality such as classroom management are considered (Praetorius et al., 2020). Expert teachers (which in the case of our study are also supervisors) have thus developed classroom management scripts for events that are typical for their subject. These scripts are comprised of those enabling conditions, event representations, and possible consequences (Wolff et al., 2021) that are particularly relevant for their every-day teaching of biology or mathematics. By considering the role of subject-specific activities and demands in future research, we can learn more about those subject-specific aspects of TPVCM that need to be addressed in teacher education and professional development. Research investigating the subject-specific challenges for classroom management when students work with digital devices and use digital tools is also needed in order to prepare future teachers (Nguyen et al., 2022) and should be considered another important future research direction in the field.

5.2 Limitations

The explorative study has limitations that need to be considered. One obvious limitation concerns the small sample of experts from just two subjects. Such a small sample reduces the power of statistical analysis. Thus, our analysis might have missed smaller expertise effects. Further research should investigate if the reported subject effects can be observed in larger samples and for other subjects, too.

A second limitation are the criteria used to define expertise. Palmer et al. (2005) propose a multi-tier procedure for defining expert teachers that also involves peer nomination and data about student learning. We could not use such data as in the German context observing the lessons of colleagues is rather uncommon and there is no student learning data available that can be linked to individual teachers. However, we used teachers' subject-specific teaching experience, certification, and their additional responsibilities in teacher education and school development as indicators of their expertise. Additionally, teachers in Germany usually teach two subjects. While no teacher in this study taught biology and mathematics, we did not control for teachers' other subjects beyond the two in focus.

Finally, we chose an on-action rather than an in-action design (i.e., we investigated TPVCM when the participants observed videos of other teachers teaching and not when they were actually teaching themselves). While such on-action designs give researchers more control over the design by ensuring that all teachers encounter the same events, they cannot provide the same level of authenticity as in-action designs. Comparing expert teachers' gaze during teaching student-centered versus teacher-centered activities and investigating their retrospective reports can be a promising approach to revealing subject-specific aspect of classroom management in an even more authentic way.

5.3 Conclusions

Despite the limitations described above, findings from this study provide first insights into the role of teachers' subject for their professional vision of classroom management (TPVCM). The results have several implications for both research and teacher education. Since this study revealed that biology and mathematic expert teachers place different emphasis on different aspects of classroom management, research into the professional vision of classroom management should review the assumption that TPVCM is a generic aspect of teacher expertise. Further investigation into possible subject effects incorporating more subject areas and classroom settings are, however, needed. Based on our study, combining eye-tracking and think-aloud data can be a promising approach for further research into subject-specific aspect of TPVCM. Second, if classroom management as a dimension of instructional quality and thus TPVCM has indeed subject-specific aspects, research into the specific challenges of subject teaching is needed. Such insights could inform the design of learning opportunities for subject-specific teacher education or professional development. Third, in order to foster teachers' TPVCM, teacher education needs to address typical settings and classroom management challenges that subject teachers will encounter in a more explicit way. Integrating courses on subject teaching and courses on general pedagogical aspects like classroom management could be particularly beneficial. Moreover, subject-specific aspects could be considered in the process of developing video or text vignettes for both assessment instruments or interventions for fostering TPVCM in teacher education or professional development.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the datasets presented in this article are not readily available as requested by the respective administrative state authorities. Requests to access these datasets should be directed to RS, stahnke@leibniz-ipn.de.

Ethics statement

The studies involving humans were approved by the Senate Department for Education, Youth and Family for Berlin, Germany. 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

RS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. MF: Methodology, Visualization, Writing – original draft, 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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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1253459/full#supplementary-material

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Relations between pre-service teacher gaze, teacher attitude, and student ethnicity

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In classrooms, ethnic minority students are often confronted with several disadvantages – such as lower academic achievement, more negative teacher attitudes, and less teacher recognition – which are all well examined in educational research. This study sought to understand if more negative teacher attitudes and lower teacher recognition are reflected in teacher gaze. Controlling for student behavior, do teachers look more on ethnic majority than on ethnic minority students? If teachers have a visual preference for ethnic majority students in their classrooms, then we would expect that teachers show a higher number of fixations, longer duration of fixations, and shorter times to first fixation on ethnic majority compared with ethnic minority students. To test this assumption, we designed an explanatory sequential mixed-method study with a sample of 83 pre-service teachers. First, pre-service teachers were invited to watch a video of a classroom situation while their eye movements were recorded. Second, after watching the video, they were asked to take written notes on (a) how they perceived the teacher in the video attended to ethnic minority students and (b) which own experiences they can relate to situations in the video. Finally, a standardized survey measured participants' age, gender, ethnic background, explicit attitudes toward ethnic minority students, self-efficacy for teaching ethnic minority students, and stereotypes associated with the motivation of ethnic minority students. Results indicated that, in contrast to our hypothesis, pre-service teachers had longer fixation durations on ethnic minority compared with ethnic majority students. In addition, pre-service teachers' explicit attitudes correlated positively with number ($r = 0.26$, $p < 0.05$) and duration ($r = 0.31$, $p < 0.05$) of fixations, suggesting that pre-service teachers with more positive attitudes toward ethnic minority students also looked more and longer on ethnic minority students. Furthermore, qualitative analyses indicated that pre-service teachers associated the disadvantaged situations for ethnic minority students with teachers' stereotypes and student language difficulties; they also referred to their own ethnic minority when reflecting on specific situations in the video. We discuss these findings considering their significance for teacher education and professional development and their implications for further research on dealing with student diversity.

KEYWORDS

ethnic minority students, teacher professional vision, fixation, eye tracking, pre-service teacher

1 Theoretical Background

Ethnic minority students tend to suffer from educational inequalities, including lower academic achievement and less teacher recognition (Gomolla, 2006; Vieluf and Sauerwein, 2018). Reasons for the emergence of these inequalities are not yet clearly understood, but there seems to be evidence suggesting that teacher attitudes and stereotypes toward ethnic minority students may play a role (Glock and Krolak-Schwerdt, 2013; Tobisch and Dresel, 2017). In education, the critical race theory has emerged as a conceptual tool to analyze ethnic minority student experiences (Ledesma and Calderón, 2015). The critical race theory began as a movement in the 1970s as a group of US lawyers and activists who wanted to combat against racism. The theory is now applied interdisciplinarily in various fields, including education, where the aim is to understand issues about day-to-day experiences at school, tests and grades, and controversies in the curriculum (Delgado and Stefancic, 2023). These issues benefit from being explored with multiple methods for a solid analysis of disadvantaged groups (Lynn and Parker, 2006). In addition to critical race theory, the intersectional theory claims that it is important to have an understanding for ethnic minority groups and their differences in social justice, inequality, and social change (Atewologun, 2018). The intersectional theory began in the late 1980s with the aim to focus on different women of different ethnicities; the term *intersectional* has since been used to cross gender and class with characteristics like race, ethnicity, nationality, citizenship, sexuality, and others (Zinn et al., 1986). Drawing upon critical race theory and intersectional theory, this mixed-methods study explores the gaze and visual preference of pre-service teachers associated with ethnic minority students in classrooms. We assumed that, independent of student behavior, pre-service teachers with negative attitudes and stereotypes toward ethnic minority students would look less frequently and less long at ethnic minority students and, instead, favor ethnic majority students in the classroom. To our knowledge, this study is among the first to report correlations between eye-tracking metrics and attitude measures of pre-service teachers. Findings of the study would thus add to the growing literature on student ethnicity, equity, and teacher professional vision to understand the emergence of inequalities in the classroom (Van Es et al., 2022).

1.1 Student ethnicity and its influence on academic achievement, teacher attitudes, and teacher recognition

Ethnicity is a complex concept, controversially discussed in the research literature. Additionally, definitions and meanings have been developed through the years. In general, ethnicity "refer[s] […] to primarily sociological or anthropological characteristics, such as customs, religious practices, and language usage of a group of people with a shared ancestry or origin in a geographical region" (Quintana, 1998, p. 28). Moreover, it describes "groups that are characterized in terms of a common nationality, culture, or language" (Betancourt and López, 1993, p. 631). In more detail, we can say that "[e]thnicity refers to a characterization of a group of people who see themselves and are seen by others as having a common ancestry, shared history, shared traditions, and shared cultural traits such as language, beliefs, values, music, dress, and food" (Cokley, 2007, p. 225). The German Statistical Federal Office (2021) defines a person as an ethnic minority person if s/he or one parent was born without German citizenship. However, this definition, excludes second generation immigrants, whose parents have German citizenship but are culturally and linguistically connected with their heritage (for a more differentiated discussion about this topic, see Will, 2019).

The Program for International Student Assessment (PISA) examined the proportion of ethnic minority students by referring to the country of birth of the students and their parents. This resulted in an unexpectedly high percentage of 22, illustrating the high proportion of ethnic minority students in Germany (Baumert and Schümer, 2001). In 2023, school authorities observed an increase of 18 percentage points of students with a foreign passport compared to the previous school year, now resulting in 39% of ethnic minority students in German classrooms (German Statistical Federal Office, 2023).

In classrooms, ethnic minority students are often confronted with a number of disadvantages, including lower academic achievement, more negative teacher attitudes, and less teacher recognition. As Gomolla, (2005, p. 46) noted, educational issues "relating to ethnic background have increased rather than diminished" (Gomolla, 2006, p. 46). The Program for International Student Assessment (Baumert et al., 2001; Hopfenbeck et al., 2017) showed that there are massive gaps in reading and mathematics competence between ethnic minority and majority students. Similarly, teacher expectations tend to be lower for ethnic minority students which also relates to ethnic minority students' lower levels of academic self-concept, self-efficacy, self-conscience, and self-esteem (Stanat and Christensen, 2006; Chmielewski et al., 2013; McElvany et al., 2023).

One possible reason for the differences in academic achievement between ethnic minority and ethnic majority students might be attributed to the way teachers interact with and evaluate their students (Glock et al., 2013a,b). For example, Glock and Krolak-Schwerdt (2013) reported that evaluations of both in-service and pre-service teachers are biased by student ethnicity, favoring ethnic majority students. Tobisch and Dresel (2017) showed that teacher ratings of student achievement expectations and achievement aspirations were accurate for ethnic minority students but overrated and too positive for ethnic majority students. The research field on ethnic minority and majority students' academic achievements shows an increasing awareness of the award gap between different ethnic groups. The award gap describes the difference between different ethnical groups in their educational level (Cramer, 2021). Prior research investigated causes of this award gap, "such as poverty, age, school type and learning style" (Cramer, 2021, p. 2). However, there are more causes, which are still unexplored. Sleeter (2008) documented that pre-service teacher expect less from ethnic minority compared with ethnic majority students. Ebright et al. (2021) reported that US teachers reprimand black students more likely than white students for the same misbehavior. Moreover, Weber (2003) showed that Turkish minority students experienced verbal and nonverbal discrimination from German teachers who believed Turkish minority girls were not deserving a high level of education. Such results often derive from studies conducted with ethnic majority teachers' attitude (Kleen et al., 2019). Other studies documented that teachers' attitudes toward ethnic minority students have been associated with teachers' judgments and behavior (Van den Bergh et al., 2010; Kumar et al., 2015) which are primarily negative (Glock et al., 2013a,b; Glock and Karbach, 2015; Glock and Klapproth, 2017). Further evidence suggests

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that teachers tend to have more negative attitudes toward (Kleen and Glock, 2018) and lower recognition of Vieluf and Sauerwein (2018) ethnic minority compared with ethnic majority students. These findings document some of the disadvantages ethnic minority students tend to experience as a result of negative teacher attitudes.

On a theoretical note, attitudes are cognitive associations when evaluating objects (Fazio, 2007). Other approaches in this discourse adopt sociological perspectives, but our approach adopts a more psychological approach with a focus on teacher attitudes. The sociological perspective debates on this topic with theories such as the critical race theory and intersectional theories mentioned above (chapter 1). With a psychological approach we aim to show relations and differences in teacher attitude toward ethnic minority students. Following the attitude theory proposed by Eagly and Chaiken (2007), teacher attitudes toward ethnic minority students can be defined as psychological tendencies that are expressed by evaluating ethnic minority students with some degree of favor or disfavor. On a conceptual level, attitudes toward ethnic minority students are important components in theory models of teacher professionalism when dealing with student diversity (Baumert and Kunter, 2013; Nett et al., 2022).

A number of studies explored pre-service teachers' attitudes toward ethnic minority students (Stephens et al., 2021). For example, Glock et al. (2019) showed that pre-service teachers had more positive attitudes toward ethnic minority students. Other aspects that are part of attitude research are self-efficacy and stereotypes (Hachfeld et al., 2012). *Self-efficacy* is a phenomenon that have an influence on the success of a person's action and can change in different situations (Bandura, 2002). It describes a person's believes in their capability to accomplish a task successfully. Thus, teachers with higher self-efficacy are more likely to be task-driven and therefore, exhibit a positive and effective behavior in the classroom (Zee and Koomen, 2016). When investigating self-efficacy in an ethnically diverse classrooms, studies tend to report differential experiences with ethnic minority and majority students (Thijs et al., 2012). Siwatu (2011), for example, reported that pre-service teachers in multicultural schools had higher self-efficacy when teaching ethnic majority students than teaching ethnic minority students. Furthermore, teachers seem to have biased expectations toward ethnic minority students (van den Bergh et al., 2010) and also perceive their relationship less positive with ethnic minority students compared with ethnic majority student (Thijs et al., 2012). In addition, teacher expectations can lead to self-fulfilling prophecies, with lower expectations being associated with lower student learning and attainment (Gentrup et al., 2020).

Moreover, *stereotypes* are attitudes toward a group of people with specific heterogeneity characteristics (Smith, 1998; Macrae and Bodenhausen, 2000). Thus, stereotypes influence a person's perception and judgment unconsciously (Smith, 1998). However, categories such as ethnical heritage, gender, social heritage, or age seem to trigger stereotypes (Chang and Demyan, 2007; Tenenbaum and Ruck, 2007). In school contexts, previous research shows that due to stereotypes, teacher expectations on academic and social competence vary with regard to the ethnical heritage of the student (Parks and Kennedy, 2007; Tenenbaum and Ruck, 2007; Glock et al., 2013a,b). Teachers were less inclined to refer ethnic minority students to giftedness and talent programs compared to ethnic majority students (Elhoweris et al., 2005). Hence, ethnic minority students tend to be challenged with more difficulties in school, teacher stereotypes and, ultimately, lower future academic perspectives than ethnic majority students (Pigott and Cowen, 2000).

In addition, *teacher recognition* is an essential component for a fundamental student-teacher relationship (Honneth, 1995; Stojanov, 2015) on a personal and professional level with positive outcomes for students' learning and achievements. It includes three interrelated modes: emotional support, cognitive respect, and social esteem (Honneth, 1995). Moreover, teacher recognition at school is a "method and aim of pedagogical practice" (Prengel, 2006). However, studies report that ethnic minority students experience negligence in classrooms (Prengel, 2013) which can lead to disadvantages in terms of performance evaluation and the assignment to social positions (Prengel, 2002; Fraser and Honneth, 2003; Helsper et al., 2005; Helsper, 2008). Thus, ethnic minority students are more likely to experience lower teacher recognition than ethnic majority students; as Vieluf and Sauerwein (2018, p. 3) note: "At school, learning takes place within and through intersubjective relations between students and teachers as among classmates, which are […] structured by recognition." Yet, recognition from teachers is a central component for a positive student-teacher relationship (Prengel, 2008, 2013). Jenlink (2009) showed that there is a fine line between social esteem and the reduction of an individual's value. Thus, according to the performance of a person, their social esteem can vary and therefore, influence their individual value. As Vieluf and Sauerwein (2018, p. 5) note, ethnic minority students "might be at greater risk of experiencing misrecognition in terms of cognitive respect and social esteem at school than their peers" (Vieluf and Sauerwein, 2018, p. 5) who are ethnic majority students. The authors documented that ethnic minority students experienced less cognitive respect from their teachers compared to ethnic majority students, concluding that ethnic minority students "were treated in an unfair or offensive way by their teachers" (Vieluf and Sauerwein, 2018, p. 17) because teachers' expectations were lower for these group of students.

Taken together, not only attitudes, self-efficacy, and stereotypes but also teacher recognition might predict pre-service teachers' judgment of ethnic minority students' competencies in classroom situations. According to the two-stage model of dispositional attributions (Trope, 1986), people base their trait judgments on two processes: Identification and categorization. The identification stage builds on situational, behavioral, and identity cues (Trope, 1986; Trope, 2004). This means that prior knowledge about the person, such as group membership (Gawronski and Creighton, 2013) is necessary to identify stereotypical characteristics of this person. The salience of stereotypical trait attributes is also positively related to attitudes (Fishbein, 2008). Thus, attitudes have been shown to predict trait judgments (Olson and Fazio, 2004).

The categorization stage builds on the behavior, identity, and the situation of the person (Trope, 1986). These three types of information have different effects on trait judgment (Trope, 1986). On the one hand behavioral and identity information positively influence the strength of trait judgments and on the other hand situational information reduce strength (Trope, 1986). As mentioned in the first stage, knowledge about the person, such as group membership (Gawronski and Creighton, 2013), is necessary to identify stereotypical characteristics which can evoke attitudes toward that group of people (Gonsalkorale et al., 2010).

Overall, these findings suggest disadvantages for ethnic minority students. However, it is still unclear what these disadvantages are based on. The question arises if these disadvantages are rooted in the gaze of teachers.

1.2 Teacher professional vision and eye tracking

Teachers' professional vision is known as a key competence of professional teachers (Berliner, 2001; Gegenfurtner et al., 2011; Lachner et al., 2016; König et al., 2022; Anderson and Taner, 2023). It is defined as the ability of teachers to recognize and interpret relevant classroom situations (Seidel and Stürmer, 2014). Seidel and Stürmer (2014) distinguish between two dimensions: noticing and knowledge-based reasoning. Through noticing, teachers identify relevant classroom situations. With reasoning, teachers interpret the identified situation.

Studies in the field of teacher professional vision are often conducted with eye-tracking technology to precisely observe teachers' eye movements during classroom events and to make them accessible for further analysis (Goldberg et al., 2021; Keskin et al., 2023). Previous eye-tracking research used a number of different metrics (Grub et al., 2020, in press); some important metrics for this present study include the number of fixations, the duration of fixations, and time to first fixation. Holmqvist et al. (2011) described fixations as a period in which the eye has little to no movement. In a broader sense, fixations are an indicator of which areas of the environment teachers attend to, and from which areas information is received from, or which stimuli are important. The number and duration of fixations describe the frequency and the period of time of a particular fixation on a particular area of interest. The time to first fixation describes the time until the first fixation on a particular area of interest occurs (Holmqvist et al., 2011; Grub et al., 2020). In order to determine certain gaze behavior from the eye movements, these parameters are meaningful. Previous studies showed that pre-service teachers frequently fixate on student behavior and levels of student engagement (Cortina et al., 2018; Schnitzler et al., 2020; Goldberg et al., 2021). Moreover, some studies have shown that pre-service teachers' pay less attention to critical classroom situations than in-service teachers (van den Bogert et al., 2014; Wolff et al., 2016). In addition, pre-service teachers are less likely to observe the whole classroom and monitor more students at the same time (McIntyre et al., 2020; Kosel et al., 2021). These are findings showing that pre-service students have more difficulty getting an overview of the class.

However, the challenge to get an overview expands with ethnic minority students in the classroom because of racism and discrimination (Schedler et al., 2019). In terms of ethnic minority students, there is little research done yet with eye tracking. Comparing the eye movements of teachers on ethnic minority and majority students requires more investigation. With eye tracking we can have access into cognitive processes and explicitly show individual behavior. Therefore, some questions are arising. If it is true that pre-service teachers allocate their attentional resources to individual students and if it is also true that teacher attitudes and stereotypes can influence levels of teacher recognition dedicated toward individual students (or particular student groups, such as ethnic minority students), then it would be interesting to explore the associations between teacher attitudes and their fixations on ethnic minority students. To our knowledge, however, previous studies have not yet examined the extent to which teacher fixations differ between ethnic minority and majority students and the extent to which attitudes, self-efficacy, and stereotypes correlate with different eye tracking measures in the classroom.

1.3 Aims of the study

This study had two aims. A first aim was to examine differences in pre-service teachers' fixations on ethnic minority and ethnic majority students. We hypothesized that pre-service teachers would have a higher fixation number (Hypothesis 1a), longer fixation durations (Hypotheses 1b), and shorter times to first fixation (Hypotheses 1c), on ethnic majority compared with ethnic minority students. A second aim was to investigate associations of the number of fixations, duration of fixations, and time to first fixation with teacher attitudes, self-efficacy, and stereotypes. We assumed that pre-service teachers gaze on ethnic minority students would correlate positively with explicit attitudes (Hypothesis 2a) and self-efficacy (Hypothesis 2b) toward ethnic minority students and negatively with stereotypes (Hypothesis 2c). To triangulate the quantitative survey and eye-tracking data, we used qualitative analyses of pre-service teachers' written notes to contextualize how they perceived the teacher behavior of the teacher shown in the video reconstruct their own lived experiences.

2 Methods

2.1 Participants

Participants were $N = 83$ pre-service teachers (66 women, 17 men) with a mean age of 21.4 years ($SD = 2.9$). Data for the study were collected during the spring term of 2022. We invited pre-service teachers from three seminars of a national teacher education program of a large university in Southern Germany to participate in the study for course credit. They were on average in their third semester ($SD = 1.6$). The pre-service teachers were enrolled in different programs preparing for four different school types: A total of 60.2% participants were enrolled in the primary education program (*Grundschule*), 18.1% participants in higher-track secondary education (*Gymnasium*), 12% in middle-track secondary education (*Realschule*), and 9.6% in lower-track secondary education (*Mittelschule*). School type did not significantly moderate any of the measures, so we combined participants across programs. Anonymity and confidentiality were guaranteed for all participants, with written informed consent obtained prior to the study.

2.2 Procedure

Pre-service teachers were invited to individual laboratory sessions to watch a 10-min-video of an authentic classroom situation on a 1,920 × 1,080 px screen while their eye movements were tracked. Before watching the video, the eye-tracking system was adjusted to the individual features of the participant based on

FIGURE 1
Visualizing of the video. We marked ethnic minority students in yellow and ethnic majority students in blue.

a nine-point calibration. Participants were seated approximately 60 cm from the display. The video showed an art class in third grade. Ethnic minority and majority students sat in front of the blackboard with their back to the camera and had a discussion with an experienced female teacher about the artist Friedensreich Hundertwasser. The students were closely listening to the teacher and were not disruptive (in terms of being loud and interrupt the interactions) through the 10-min-video. In the class were 13 students with five of them being ethnic minority students. However, the pre-service teachers who participated in our study were not told who of the students came from ethnic minorities. The teacher in the video encouraged the students to create own ideas for redesigning the school building following Hundertwasser's aesthetic and style. Figure 1 shows a screenshot of the stimulus material.

Participants were instructed to watch the video and focus on the behavior of the teacher while she interacted with the students. Afterwards, the pre-service teachers were asked to take written notes on two questions: "How does the teacher interact with ethnic minority students? Do you remember situations in which you made experiences with ethnic minority students in class?" Finally, participants completed a multi-item questionnaire with items on their age, gender, semester, study program, ethnic background, explicit attitudes toward ethnic minority students, self-efficacy for teaching ethnic minority students, and stereotypes associated with the motivation to learn of ethnic minority students.

2.3 Measures

Measures included eye movements, demographic information, explicit attitudes, self-efficacy, and stereotypes.

Eye movements were recorded with a Tobii Pro Spectrum screen-based eye-tracker with a temporal resolution of 1,200 Hz and analyzed with the Tobii Pro Lab 1.123 software.[1] From the classroom videos, two ethnic minority students (one female, one male) were chosen because they were unambiguously identifiable as ethnic minority based on skin color and first name. These two ethnic minority students were matched with two ethnic majority students (one female, one male) who showed similar levels of hand-raising behavior, classroom talk, and sitting position. All four target students were defined as areas of interest (AOI). AOIs were created manually. Because the video was dynamic, AOIs were transient and of varying size, with an average pixel size of 88 × 146 px for the ethnic minority students and 84 × 145 px for the ethnic majority students. Data for each AOI were aggregated to determine the number of fixations, fixation duration, and time to first fixation on ethnic minority vs. majority students.

Demographic information was measured with items on pre-service teacher age (in years), gender (female, male, nonbinary), teacher education program (primary, lower-secondary, middle-secondary, higher-secondary), number of semesters, and birth place of their parents (coded as 0 = Germany, 1 = Russia, 2 = Macedonia, 3 = Poland, 4 = Romania, 5 = Thailand, 6 = Kazakhstan, 7 = Turkey, 8 = Hungary, 9 = Moldova, 10 = Slovakia, 11 = Kosovo).

Explicit attitudes toward ethnic minority students were measured with a 101-point feeling thermometer (Alwin, 2007). We adapted the instruction from Norton and Herek (2013) and asked: "Think of an imaginary thermometer with a scale from zero to 100. The warmer or more favorable you feel toward ethnic minority students, the higher the number you should give it. The colder or less favorable you feel, the lower the number. If you feel neither warm nor cold toward ethnic minority students, rate it 50." Lower rating (minimum = 0) indicated more negative feelings and higher ratings (maximum = 100) indicated more favorable feelings.

Self-efficacy for teaching ethnic minority students was measured with four items adapted from Hachfeld et al. (2012) on a 5-point Likert scale. An example item is: "I am confident that I can adapt my teaching to the needs of ethnic minority students." Cronbach's alpha was $\alpha = 0.98$.

Stereotypes about the school-related motivation of ethnic minority students was measured with five items adapted from Hachfeld et al. (2012) on a 5-point Likert scale. An example item was: "Ethnic minority students are less interested in school-related topics." Cronbach's alpha was $\alpha = 0.99$.

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2.4 Analysis

To address Hypotheses 1a–1c, a series of Mann–Whitney *U* Tests were performed because the data were non-normally distributed. Thus, we used non-parametric methods to analyze differences in the number of fixations, duration of fixations, and time to first fixation on ethnic minority and ethnic majority students. Moreover, we performed a linear regression. We defined attitudes, self-efficacy, and stereotypes as independent variables and we analyzed number of fixations, duration of fixations, and time to first fixation as dependent variables. To address Hypotheses 2a–2c, one-tailed Pearson correlations using attitudes, self-efficacy, stereotypes, and all fixation measures were calculated. The written notes were analyzed qualitatively following the systematic data analysis approach. Braun and Clarke (2006) noted that a thematic analysis is helpful in analyzing qualitative data when aiming to search for patterns or themes in the data material. Therefore, two trained raters ($\kappa = 0.85$) used their guideline to conduct a thematic analysis with our qualitative data. Following an inductive approach, we identified three categories (positive, negative, and neutral) and five subcategories (motivation, stereotypes, no difference, language difficulties, and experience) that emerged from the written notes in which pre-service teachers reported positive, negative, and neutral thoughts with respect to their own lived experiences and how they perceived the teacher behavior in the video.

3 Results

3.1 Differences in fixations on ethnic minority vs. majority students

Hypothesis 1 assumed that pre-service teachers would have a higher fixation number (Hypothesis 1a), longer fixation durations (Hypotheses 1b), and shorter times to first fixation (Hypotheses 1c), on ethnic majority compared with ethnic minority students. Table 1 reports mean and standard deviation estimates for all fixations measures per student group. Mann–Whitney *U* Tests revealed a significant difference in fixation duration, $U = 379.00$, $Z = -2.10$, $p < 0.05$, with longer fixation durations on ethnic minority compared with ethnic majority students. Differences in fixation number and time to first fixation were statistically non-significant. Moreover, the regression coefficient shows that there is an influence on fixation duration. Therefore, pre-service teachers with a positive attitude toward ethnic minority students have longer fixations toward ethnic minority students. Since the *value of p* (<0.04) is smaller than 0.05, this relation is statistically significant. Hence, our findings show a relation between pre-service teachers' fixation duration and ethnic minority students (see Table 2).

3.2 Correlations between fixation and attitude measures

Hypothesis 2 assumed that pre-service teachers' gaze on ethnic minority students would correlate positively with positive explicit attitudes (Hypothesis 2a) and self-efficacy (Hypothesis 2b) toward ethnic minority students and negatively with stereotypes (Hypothesis 2c). Table 3 presents Pearson correlations between these measures. Results show significantly positive correlations of explicit attitudes toward ethnic minority students with the number ($r = 0.26$, $p < 0.05$) and duration of fixations ($r = 0.31$, $p < 0.05$) on ethnic minority students. Analyzing pre-service teachers' ethnical background in this context showed no significant correlation.

3.3 Qualitative analysis

To identify additional thoughts related to ethnic minority students, we asked the pre-service teachers to explain how they perceived the teacher behavior shown in the video and to reconstruct their own lived experiences (Braun and Clarke, 2006). The three main categories were positive, negative, and neutral, referring to participants' assessment of the behavior of the teacher shown. Overall, pre-service teachers stated positive (53 units), negative (46 units), and neutral (43 units) perceptions of teacher behavior in the video and about their own lived experiences (see Table 4 for details).

In the *positive* category, pre-services teachers reported for example: "In addition, she is very considerate of the ethnic minority students"; "[…] and let them speak often"; "the teacher […] complimented […] the ethnic minority students."

In the *negative* category, pre-service teachers reported for example: "[I]t seemed to me that the teacher paid less attention to the ethnic minority students and rarely picked them"; "I noticed that she strongly complimented ethnic majority students"; "I can imagine that she did not include ethnic minority students who have less language skills"; "[h]aving ethnic minority background myself, I could see that in the teachers' behavior."

In the *neutral* category, pre-service teachers reported for example: "I believe that the teacher did not treat the ethnic minority students any different"; "[…] the teacher makes no distinction between ethnic

TABLE 1 Mann–Whitney U test.

	M		*SD*		*U*		*Z*		*p*	
	Ethnic minority	Ethnic majority	Ethnic minority	Ethnic majority	Ethnic minority	Ethnic majority	Ethnic minority	Ethnic majority	Ethnic minority	Ethnic majority
Number of fixation	211.10	119.54	97.76	37.21	446.00	468.00	−1.30	−1.04	0.29	0.30
Fixation duration	3455.54	251.80	4972.94	109.50	379.00	435.50	−2.10	−1.41	0.04	0.16
Time to first fixation	9700.31	16318.57	9514.89	12245.81	531.00	476.00	−0.31	−0.95	0.76	0.35

TABLE 2 Regression analysis of number of fixation, duration of fixation, and time to first fixation with attitudes, stereotypes, and self-efficacy.

	Number of fixation								Duration of fixation								Time to first fixation							
	Ethnic minority students				Ethnic majority students				Ethnic minority students				Ethnic majority students				Ethnic minority students				Ethnic majority students			
	b	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*
Attitudes	0.93	0.73	0.19	0.21	−0.06	0.73	−0.03	0.84	74.55	35.53	0.30	0.04	0.50	0.78	0.10	0.53	−68.97	67.52	−0.15	0.31	154.80	87.77	0.25	0.08
Stereotypes	14.91	14.63	0.26	0.31	−2.20	14.63	−0.10	0.70	−105.04	712.16	−0.04	0.88	2.94	15.72	0.05	0.85	−1898.88	1353.41	−0.35	0.17	146.24	1759.18	0.02	0.93
Self-efficacy	−16.93	16.99	−0.24	0.32	−0.18	16.99	−0.01	0.98	225.10	827.04	−0.07	0.79	−5.35	18.25	−0.07	0.77	2002.09	1571.17	0.31	0.21	−1097.12	2042.95	−0.13	0.59

minority and majority students"; […] "[…] she calls each child without paying attention to their ethnic background and leaves none out."

The written notes of the pre-service teachers showed a wide range of positive, negative, and neutral viewpoints, which might indicate no explicit racist bias or any preferences for ethnic majority or minority students. To analyze the written notes more deeply, these three categories were subsequently specified into five more detailed subcategories. The subcategories *motivation*, *no difference*, and *stereotypes* refer to the assessment of the pre-service teachers on the behavior of the teacher shown. The subcategory *language difficulties* reflect statements of students for whom German was not their first language. The subcategory *experience* refers to own experiences of the per-service teachers. Pre-service teachers stated most frequently motivation (54 units) and no difference (43 units), followed by stereotypes (35 units), language difficulties (8 units), and experience (4 units).

In the *motivation* subcategory, pre-service teachers reported for example: "She tries to bring all the ethnic minority students along by speaking very clearly and slowly, also gesticulating more to what is being said […]"; "[t]he ethnic minority students are also motivated to speak again and again"; "[…] when the ethnic minority student said something, she repeated and strongly emphasized his answer positively."

Looking into the subcategory *no difference*, pre-service teachers reported for example: "If a child did not abide by the rules, she pointed this out, regardless of the ethnic minority background"; "she does not favor or disadvantage any of the ethnic minority or majority students"; "I do not remember any special or different treatment."

Furthermore, in the *stereotypes* subcategory, pre-service teachers reported for example: "I feel that the teacher somewhat neglected the ethnic minority students, even though these students wanted to participate and engage in class"; "[…] it can also be seen that the teacher unconsciously makes a distinction between ethnic minority and majority student"; "The compliments could be a bit more pronounced with ethnic minority students, because I noticed that she complimented a lot of ethnic majority students and ignored the ethnic minority students. I think she was judgmental."

In the subcategory *language difficulties,* pre-service teachers reported for example: "You could hear that [the ethnic minority student] had difficulties with sentence structure. The teacher could have been more responsive to him"; "[…] forgets the special support ethnic minority students need because they have not yet fully mastered the language"; "[ethnic minority students] need special language support because they do not fully master the language. She did not pay attention to that."

Lastly, in the *experience* subcategory, pre-service teachers reported for example: "I have an ethnic minority background myself, I could see that in the teachers' behavior"; I also have an ethnic minority background and therefore know that this sometimes happens"; "I can also say from my experience that this happens very often and also happened to me because I also have an ethnic minority background."

By dividing the categories into these five subcategories, it can be seen that pre-service teachers mostly recognize teacher behavior with a positive attitude toward ethnic minority students with the explanation that the teacher is motivating the students by highlighting their behavior and inviting them to participate. Only a few pre-service teachers reconstructed their own lived experiences. This can be partly

TABLE 3 Correlation of eye-tracking metrics with explicit attitudes, stereotypes, and self-efficacy.

Metrics	Explicit attitudes	Stereotypes	Self-efficacy
Number of fixation on ethnic minority students	0.26*	0.09	0.18
Number of fixation on ethnic majority students	−0.04	−0.02	−0.03
Fixation duration on ethnic minority students	0.31*	0.09	0.14
Fixation duration on ethnic majority students	0.13	−0.05	0.02
Time to first fixation on ethnic minority students	−0.25	0.06	−0.03
Time to first fixation on ethnic majority students	0.23	−0.12	−0.04

*$p < 0.05$.

attributed to the fact that (a) only 20.8% of the participants reported of own ethnic minority background and (b) participants reported 11 different cultural heritages, hampering systematic comparisons.

4 Discussion

The aim of this study was to explore relations of pre-service teachers' gaze, attitudes, and student ethnicity. With respect to the first aim of this study, an analysis of pre-service teacher fixations on ethnic minority and majority students showed a significant difference in terms of fixation duration: Contrary to our hypothesis, pre-service teachers fixated longer on ethnic minority than on ethnic majority students. Reasons for this visual preference are likely independent of student behavior (Goldberg et al., 2021), hand-raising (Kosel et al., 2021), or classroom talk (Kosel et al., 2021) because we controlled for these parameters. This visual preference can neither be explained by the pixel size of the AOIs which were comparable for ethnic minority and majority students. Instead, a likely explanation for the longer fixation durations on ethnic minority students might be associated with the positive attitudes and levels of self-efficacy that pre-service teachers reported when working with ethnic minority students, which could demonstrate their positive levels of teacher recognition (Vieluf and Sauerwein, 2018).

An alternative explanation is that pre-service teachers had longer fixation durations on ethnic minority students because they required more time monitoring students who potentially needed guidance (Schnitzler et al., 2020) or were assumed to show off-task behavior (Hendrickson, 2018; Ebright et al., 2021), which would reflect their metacognitive monitoring (Gegenfurtner et al., 2020). However, it can also be interpreted as unconscious bias and deficit thinking which is itself an example of the award gap. Findings of the present study confirm previous evidence reported in Ebright et al. (2021) because pre-service teachers fixate more and longer ethnic minority students.

Such an explanation would also emerge when reflecting on the qualitative analysis of the written notes taken after watching the classroom video, in which some pre-service teachers indicated an awareness of the students' language difficulties, which could have resulted in a higher allocation of attentional resources. Furthermore, the findings indicate that pre-service teachers' explicit attitude correlates with their duration of fixation and number of fixations on ethnic minority students which indicates that a positive explicit attitude toward ethnic minority students was related to more and longer fixations on ethnic minority students. However, we could not find any associations with self-efficacy and stereotypes. This might be because pre-service teachers were not in the position of teaching but watching a classroom video on action, in which they might not feel the presence and affiliation and shared histories with the students (Short et al., 1976; Kreijns et al., 2004). Another possible explanation could relate to a self-serving bias: pre-service teachers were perhaps less willing to admit they had negative stereotypes on pre-service teachers' motivation to learn—which is not specific to our study but a frequent problem in survey-based research in the social sciences more broadly.

Looking at the qualitative data, the written notes reflect a broad range of positive, negative, and neutral comments. While most of the pre-service teachers reported positive notes—suggesting that the in-service teacher in the video had a positive, motivating approach toward ethnic minority students—other pre-service teachers commented on negative aspects of the observed classroom situation (such as the management of student language difficulties) and their own lived experiences. Regarding pre-service teachers' visual focus of attention to ethnic minority and ethnic majority students, the results showed that the pre-service teachers' descriptions of student-teacher relationship shown in the video can be explained by the triangulation of the qualitative and quantitative data. The results may indicate that paying attention to social relations in the classroom requires teachers to have more and longer fixations on disadvantaged students. Prior studies have shown that teachers often distribute their attention unevenly among their students (Dessus et al., 2016; Haataja et al., 2019). However, these studies focused on teachers' expertise and students' achievements. The findings of the present study indicate that pre-service teachers' pay attention to the social relations between the teacher and the students shown in the video and thus report more positive observations. Other negative reports in terms of stereotypes, language difficulties, and own experiences may indicate that pre-service teachers' can detect the complexity of classroom situations and therefore, distribute their attention among ethnic minority and majority students. In terms of practical implications, these findings can inspire video-based teacher education programs to let pre-service teachers reflect on their own attitudes and stereotypes and afford pre-service teachers a safe space for reconstructing their own, perhaps disadvantaged, experiences made in their own school biographies. This could be done in such a way that pre-service teachers have the opportunity to play certain situations in classrooms through videos and explicitly have the opportunity to discuss them with fellow students or even experts. In addition, by showing them their own gaze movements after watching classroom videos, is a possibility to use the eye-tracking device as an instrument of reflection.

This study has some limitations that should be noted. First, we limited our work on using an authentic classroom video which was shown in the laboratory on a screen-based eye tracker, so we could not

TABLE 4 Description of written notes of pre-service teachers.

Way of making the statement	Statement	Category
Positive (4)	She appears very confident and focused on the students with an ethnic minority background. She tries to bring all the ethnic minority students along by speaking very clearly and slowly, also gesticulating more to what is being sad and always seeks eye contact with the students. The ethnic minority students are also motivated to speak again and again. I noticed this very positively.	Motivation Motivation Motivation Motivation
Neutral (2)	In the video, all students are treated equally, i.e., it is not really noticeable that a few children have an ethnic minority background. Everyone gets almost the same amount of speaking time.	No difference No difference
Neutral (2) Positive (2) Negative (1)	Personally, I think that in the video you hardly notice the difference between students with a migrant background and students without a migrant background. The teacher treats every student the same and probably has no prejudices. The students with an ethnic minority background also have their say. In addition, she is very considerate of the students ethnic minority students, because she asks, for example, what the task was again. However, I noticed that she did not call on the students or students with an ethnic minority background for the repeat questions.	No difference No difference Motivation Motivation Stereotypes
Positive (3)	The teacher does it very well with the ethnic minority students and let them speak often. If they express themselves badly, she improves their answer for the whole class as a repetition. Thus, not only the children with an ethnic minority background feel addressed, but the whole class.	Motivation Motivation Motivation
Negative (1) Positive (1) Negative (1)	At first it seemed to me that the teacher paid less attention to the ethnic minority students and rarely picked them. However, when the ethnic minority student said something, she repeated and strongly emphasized his answer positively. Above all, I noticed that she strongly complimented ethnic majority students.	Stereotypes Motivation Stereotypes
Neutral (1)	The teacher does not make a difference to students with an ethnic minority background compared to students without an ethnic minority background, at least I have not noticed anything conspicuous in this direction.	No difference
Negative (2)	The teacher is quite nice to everyone, but I noticed that she calls the same students every time and often does not give the other children who come forward the opportunity to say something. Mostly the children with an ethnic minority background were neglected.	Stereotypes Stereotypes
Neutral (1) Positive (1)	I did not notice anything. I would say, she does not favor or disadvantage any of the ethnic minority or majority students. Perhaps she gives students with an ethnic minority background, because they can not speak German so well, a little more time and improves them more, or gives them assistance.	No difference Motivation
Negative (1) Positive (2) Negative (1)	I had the feeling that the students with an ethnic minority background were on the right side of the classroom, while the students without an ethnic minority background tended to gather on the left side. I did not like this arrangement at all. The LK mainly interacted with and praised the students who sat on the left side, i.e., the children without an ethnic minority background. She also used a lot of facial expressions and gestures and used her hands to communicate non-verbally and thus in a way that everyone could understand. The LK was facing the children on the right side and sought eye contact with the students while speaking and explaining.	Stereotypes Motivation Motivation Stereotypes
Negative (3)	In some cases, the teacher praised a child without an ethnic minority background more than a child an ethnic minority background. Children with an ethnic minority background were simply called out a little less by the teacher. I can imagine that the teacher has unconscious prejudices and does not know that she talks more to the children without an ethnic minority background.	Stereotypes Stereotypes Stereotypes
Positive (5)	The teacher gives the students time to formulate their point of view/comment; if it is incomprehensible, the teacher repeats it aloud to the whole class; the teacher notices all the students and lets everyone have their say; if there is any uncertainty about the language, the teacher helps; the teacher works a lot with "symbols" (e.g., a question mark painted in the air); the teacher has one of the students explain the task again so that everyone really understands what the task is.	Motivation Motivation Motivation Motivation Motivation
Positive (1) Negative (2) Positive (1)	I do not think the teacher has any problems involving the students, she rather complemented the collaboration of the ethnic minority students. However, I would have liked her to involve more children in between and not always call on the same ones. I would have liked to see more control in the interaction, but perhaps she has prejudices and therefore did not care about the participation of children with an ethnic minority background. Of course, I can only speculate about this, because a video cannot show me the whole class situation and its climate. The students an ethnic minority background were also called up a few times by the LK in order to let them participate in the class discussion, which was important in order not to lose them.	Motivation Stereotypes Stereotypes Motivation

(Continued)

TABLE 4 (Continued)

Way of making the statement	Statement	Category
Neutral (1)	In my opinion, she treated all the children the same. When the children were allowed to call each other, it was noticeable that the children with an ethnic minority background were called less. So the children called on their peers and neglected the children with an ethnic minority background.	No difference
Neutral (3)	In my opinion, the teacher treated all students equally. She did not favor or neglect anyone. If a child did not abide by the rules, she pointed this out to the children, regardless of their ethnic minority background. I noticed positively that she did not discriminate.	No difference No difference No difference
Negative (2)	Ignores or perceives a child only peripherally, but perhaps because she herself has an unfavorable positioning in the classroom. But perhaps she has deliberately placed herself there so that she can only pay attention to children without an ethnic minority background and does not have to involve the others in the interaction.	Stereotypes Stereotypes
Negative (3)	the selection of students who are allowed to say something is a bit one-sided. In fact, she only calls on children without an immigrant background. I suspect that she has prejudices.	Stereotypes Stereotypes Stereotypes
Positive (1)	She seems open because she wants to explain everything to the child with an ethnic minority background in detail and therefore speaks slowly and clearly.	Motivation
Neutral (2)	It seemed to me that the teacher makes no distinction between ethnic minority and majority students. I do not remember any special or different treatment.	No difference No difference
Positive (1) Negative (1)	The teacher has introduced certain rule. In this way, the children an ethnic minority background can also orient themselves well. The boy in the first row did not have a partner in the marble rounds (he was as student with an ethnic minority background); the teacher did not react to this. She should have pointed out to the girls next to this boy that they should include him in their conversation. I found this negative.	Motivation Stereotypes
Negative (3) Negative (1)	I think she generally did not involve the students who did not participate on their own. I felt there was a lack of control. But maybe it's also because there were students with an ethnic minority background in the class and they tend to withdraw because they do not speak the language.	Stereotypes Stereotypes Language difficulties
Neutral (1) Positive (1) Negative (2)	I think the teacher is very similar and confident with all the students. Perhaps she speaks so slowly, especially because of the students who do not yet understand the German language so well, but that is only one option. Also, the fact that she underlines many assignments with gestures can help all the students (but possibly the children with an ethnic minority background). I think it is a pity that she does not direct the conversation a bit, since not all students are called with the same frequency. I can imagine that she did not include ethnic minority students who have less language skills. This students are less involved.	No difference Motivation Motivation Stereotypes Language difficulties
Neutral (1) Positive (2)	I do not see much difference with those without a migrant background. She lets the students call on each other, which prevents favoritism. She speaks to everyone equally, praises and encourages them.	No difference Motivation
Neutral (1)	So basically, you could not really see a different behavior toward children with a multicultural background.	No difference
Neutral (1)	She does not treat migrant students differently from other students.	No difference
Neutral (2)	Toward the end, when the children had questions, all questions were answered in detail. So both from children with but also without an ethnic minority background.	No difference No difference
Neutral (4)	She integrates them well into the lessons. What I can tell is that she calls each child without paying attention to their ethnic background and leaves none out. She has no prejudices. At the beginning she asks one student to come to the sitting circle. She treats the class as a whole and also the students with an ethnic minority background equally.	No difference No difference No difference No difference
Neutral (2)	She makes a very open impression to all children, without prejudice or prejudicial remarks. She calls on different children who come forward.	No difference No difference
Neutral (1)	The teacher in the video treats all students the same, at least there were no differences in the brief glimpse.	No difference
Neutral (1) Positive (2)	She seems very friendly and does not discriminate when speaking to non-migrant students. She speaks loudly and clearly so that the students understand her well.	No difference Motivation
Positive (2)	She speaks very slowly and clearly, so that everyone can understand it well. She also lets them work a lot in class and praises them.	Motivation Motivation

(Continued)

TABLE 4 (Continued)

Way of making the statement	Statement	Category
Positive (2)	She speaks slowly and clearly; repeats the task several times; has a child repeat the task again; uses technical terms, but also paraphrases them with simpler words; addresses all children so that everyone can say something; repeats what the children have said; gives clear tasks with an exact time; children see exact structured plan and procedure.	Motivation Motivation
Neutral (1)	She makes no distinction between the pupils. Everyone who comes forward may have their say.	No difference
Neutral (1) Positive (1)	Very professional and self-confident → probably does not (anymore) really perceive students with an ethnic minority background → indifference; does not favor anyone, everyone is allowed to say something (regardless of an ethnic minority or majority background)	No difference Motivation
Neutral (1)	In the video, the teacher makes no distinction between students with an immigrant background and students without an immigrant background.	No difference
Neutral (1)	I found that the teacher did not treat the immigrant students differently, except that twice she repeated a difficult German word again.	No difference
Negative (2) Negative (1)	I feel that the teacher somewhat neglected the ethnic minority students, even though these students wanted to participate and engage in class. As a result, their potentially valuable contributions were mostly lost. Another aspect, I want to add is, that it can also be seen that the teacher unconsciously makes a distinction between ethnic minority and majority students. I think she was judgmental. Having ethnic minority background myself, I could see this from the teachers' behavior.	Stereotypes Stereotypes Experience
Positive (1) Negative (1)	She encourages them partially through praise, but sometimes forgets about the special support they need. These children need special language support because they do not fully master the language. She did not pay attention to that.	Motivation Language difficulties
Neutral (1)	I have not noticed that the teacher treats the students with an ethnic minority background differently.	No difference
Positive (2)	She appears calm and patient in her interactions with the students. She has introduced some signs to ensure that, for example, the respective groups of students know when she is referring to them.	Motivation Motivation
Positive (1) Negative (1)	She often calls on children an ethnic minority background first after asking a question, but it is also noticeable that the teacher unconsciously makes distinctions between students with and without an ethnic minority background.	Motivation Stereotypes
Positive (2)	She speaks even more clearly and slowly to these students. However, she generally articulates the words very clearly and reinforces what she says with gestures, facial expressions, and the PowerPoint presentation. If she does not immediately understand something, she asks the student about it. She does this equally for all students.	Motivation Motivation
Neutral (1)	She makes an effort to call on all students equally, even though it does not always work out perfectly since many students call themselves to answer. Students with an ethnic minority background sit at different tables, so there is always a student with an ethnic minority background sitting next to one without.	No difference
Positive (2) Neutral (1)	I think the teacher handles students with an ethnic minority background very well. She uses a lot of gestures and familiar symbols. For example, she calls the children to sit in the cinema-style seats or draws a question mark in the air to indicate that they can now ask questions about the task. Additionally, she always speaks slowly, loudly, clearly, and distinctly. When children do not express themselves clearly, the teacher follows up with them again. However, she does this for all children, not specifically targeting those with an ethnic minority background. Furthermore, the teacher uses pictures extensively when working on the board. She also has one of the students re-explain the task in their own words, which is helpful for the other children.	Motivation Motivation No difference
Neutral (1)	The teacher treats students an ethnic minority background the same as students without an ethnic minority background.	No difference
Positive (1) Negative (1)	The teacher spoke to all children in adapted language. Foreign words like "Mosaic," which might be unfamiliar to children an ethnic minority background, were explained. However, it would have been beneficial to clarify or repeat other words like "Style" as well, so that children an ethnic minority background also have the opportunity to understand the task.	Motivation Language difficulties
Neutral (1)	She treats every child equally, regardless of whether they an ethnic minority background or not.	No difference
Positive (2)	She appears competent and empathetic. She speaks slowly and clearly, emphasizing important (question) words to highlight them for the students. In this way, all children, including those an ethnic minority background, can easily follow the lesson.	Motivation Motivation

(Continued)

TABLE 4 (Continued)

Way of making the statement	Statement	Category
Negative (1) Negative (1) Negative (1)	It is unfortunate that the boy in the white shirt who was sitting in the front center was not called on for a long time. Often, the blonde girls in front of him were called on by the teacher. It seems that the same students without an ethnic minority background were frequently given a chance to speak initially. However, it's essential to provide language support, especially to students with an ethnic minority background, but they are not encouraged to speak. I find this very disappointing. I also have an ethnic minority background and therefore know that this sometimes happens.	Stereotypes Language difficulties Experience
Negative (1) Negative (1) Negative (1)	I noticed that she called on students with an ethnic minority background less frequently, which I find regrettable because we want to encourage them to speak. The praising could be more pronounced for students an ethnic minority background, as I observed that she mostly praised many students without an ethnic minority background. Based on my experiences, I can also say from my experience that this happens very often and also happened to me because I also have an ethnic minority background.	Language difficulties Stereotypes Experience
Positive (1) Negative (1) Negative (1)	She encourages them partially through praise but sometimes forgets the special support ethnic minority students need because they have not yet fully mastered the language. I have an ethnic minority background myself, I could see that in the teachers' behavior.	Motivation Language difficulties Experience
Neutral (1) Positive (1)	She treats all children equally, in fact. During an activity, she asks the child with an ethnic minority background to repeat the sentence clearly once more. This is positive because these children need special support.	No difference Motivation
Negative (1) Negative (1) Negative (2)	I noticed that the teacher often calls on the same children (often with German names) and these children also frequently call on the same classmates. As a result, some children often do not get a chance to speak, even though they consistently raise their hands. Among them is a boy with an ethnic minority background who sat near the front of the class on the floor. He almost always volunteered, but was only called on a few times. You could hear that he had difficulties with sentence structure. The teacher could have been more responsive to him by helping him construct a complete sentence (not just asking "Trees?") so that everyone could understand what he meant. Overall, the teacher could have been more attentive to ensuring that all children actively participate in the class, rather than always calling on the same ones. I can imagine that this might create a difference in treatment between students with and without an ethnic minority background, and that could influence how students interact with each other as well.	Stereotypes Language difficulties Stereotypes Stereotypes
Neutral (1) Positive (1)	She treats all children equally, including those without an ethnic minority background. The children seem to be well integrated into the class community, and no one is sitting isolated. Nobody is excluded from the conversation.	No difference Motivation
Negative (3)	The teacher seems a bit disinterested when it comes to interacting with students with an ethnic minority background. They are not called on as often in class when they raise their hands compared to the students without an ethnic minority background. I would have liked to see more proactive engagement from the teacher in the interaction. Perhaps the teacher has some biases, which could be the reason for not encouraging the participation of students with an ethnic minority background.	Stereotypes Stereotypes Stereotypes
Neutral (1)	I did not perceive any difference in how the teacher in the video interacted with children with or without an ethnic minority background.	No difference
Neutral (1) Negative (1) Positive (1)	I did not notice much regarding this, but she calls on every child, regardless of whether they have an ethnic minority background or not, and includes everyone in the discussions. At certain points, maybe one group is called on more frequently than the other. The topic itself, which is art, provides a lot of freedom. During such a topic, nobody is excluded; instead, all students are encouraged to contribute. Allowing them to create their own painting in the style of Hundertwasser gives them the freedom to express their creativity.	No difference Stereotypes Motivation
Positive (2)	She includes students with an ethnic minority background in the class without excluding them through special treatment. She speaks very slowly and clearly and emphasizes her statements with pictures and symbols.	Motivation Motivation
Neutral (2) Negative (1)	I believe that the teacher did not treat the ethnic minority students any different. There are no significant differences in her treatment. However, I have noticed that students without an ethnic minority background are sometimes more involved and included in the discussions.	No difference No difference Stereotypes

(Continued)

TABLE 4 (Continued)

Way of making the statement	Statement	Category
Positive (3)	The teacher made a great effort to integrate the children with an ethnic minority background just like the others, ensuring they could participate in class discussions. For example, even when many other children had already volunteered, she waited for others to have a chance to speak, knowing they might need more time. She also provided corrections and follow-up questions when sentences were not formulated correctly. Additionally, she incorporated syllable clapping to help some children who might be unfamiliar with certain words. I believe the teacher's approach toward students with an ethnic minority background was commendable.	Motivation Motivation Motivation
Neutral (1) Positive (1) Neutral (1)	She does not explicitly highlight the heritage. She repeats difficult words slowly and uses syllable clapping. She explains the task verbally and also displays it in writing on the board. Every student is treated equally and has the same opportunity to participate in the class. I find this very positive.	No difference Motivation No difference

control classroom dynamics shown in the video (e.g., seating arrangement or situational circumstances). In addition, we also could not control factors such as bright colors in the video or restless movements of pre-service teachers' pupils. Still, authentic classroom videos are often used studies on teacher professional vision and teacher noticing (Cortina et al., 2018; Henderson and Hayes, 2018; Grub et al., 2022; Van Es et al., 2022; Keskin et al., 2023). Future research can consider using a mobile eye tracker in real-world or virtual reality classrooms to explore teacher fixations in action. Second, our sample included only pre-service teachers which limits the generalizability of our results to the population of in-service teachers. A comparison between pre-service and in-service teachers can be addressed in future studies. Third, we observed four students who were similar in their classroom behavior and pixel size. To extend these first exploratory results presented here, future studies could consider adding a larger number of students, or even all students in class. Fourth, we used questionnaire items to assess explicit attitudes toward ethnic minority students. Future studies might want to consider using implicit association tests to minimize the effects of a self-serving bias on any of the attitude measures (Glock et al., 2013a,b; Glock and Karbach, 2015; Kleen et al., 2019; Tobisch and Dresel, 2017).

In conclusion, this study is among the first to explore the relations between attitude and fixation measures in a sample of pre-service teachers. The study is also among the first to address any differences in teacher gaze between ethnic minority and majority students. Future research is encouraged to address the nexus of teacher professional vision and teacher attitudes as an important aspect of teacher professionalism in culturally diverse classroom contexts.

Data availability statement

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

Author contributions

ÖK: Writing – original draft. SG: Writing – review & editing. IK: Writing – review & editing. AG: Conceptualization, 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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Classroom chronicles: through the eyeglasses of teachers at varying experience levels

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Introduction: Teachers face the intricate task of managing diverse classroom situations, directly affecting student learning outcomes. Many preservice and beginning teachers, however, find classroom management challenging. Effective classroom management hinges on the teacher's ability to notice and interpret visual cues that signal potential issues - a proficiency termed 'professional vision.'

Methods: In this study, we used mobile eye-tracking glasses to assess the professional vision of 22 preservice, 17 beginning, and 19 experienced teachers as they instructed their classes.

Results: Our findings revealed no discernible differences in the efficiency of visual processing across varying teaching experience levels throughout the lesson. Interestingly, by the lesson's end, preservice teachers demonstrated a slight uptick in fixation counts compared to the onset. As for perceptual span, overall teaching experience did not significantly influence the dispersion of fixations, though experienced teachers exhibited a more expansive visual span at the lesson's commencement than its conclusion. In examining mental effort, teaching experience did not notably impact the average fixation durations. Yet, preservice teachers registered a subtle decrease in fixation durations as the lesson progressed to its end. In conclusion, this study showed that professional vision manifests differently across teaching experience levels.

Discussion: Given its nuanced influence on classroom management and student engagement shown in prior research, our study underscores its importance in pedagogical training.

KEYWORDS

eye tracking, mobile eye tracking, teacher, expertise, visual expertise, professional vision, classroom management

1 Introduction

Picture yourself as a secondary school teacher standing in front of a classroom filled with teenagers engaged in all sorts of off-topic activities. To your left, a group of pupils is lost in casual conversation rather than the lesson. To your right, a pair of pupils fiddles with a mobile phone. The digital learning board you rely upon is malfunctioning, while a pupil right in front of you raises a hand, eager to pose a question. Amidst this, which event do you tackle first? What considerations guide your decisions in this moment?

What you just read, is part of the teachers' daily practice, where a lot is going on that the teachers must somehow manage (Berliner, 2001). The technical term for this is 'classroom management' and it refers to managing pupils with the aim to create an atmosphere that encourages their learning (Brophy, 1988; Doyle, 2006). It is not only necessary to keep order during a lesson, but far more important, it enables pupils to learn (Berliner, 2001; Hattie, 2009). However, it is a skill, that teachers often struggle with in their daily practice (Van Tartwijk et al., 2011). Effective classroom management requires that teachers notice and monitor what is going on in the classroom and that they meaningfully interpret what it means for their actions to encourage pupils' learning – a skill referred to as 'professional vision,[1] (Berliner, 2001; Van Es and Sherin, 2002; Sherin, 2014). This is a skill that a lot of beginning teachers struggle with, and many experienced teacher excel in (Sabers et al., 1991). This phenomenon has been studied by means of diverse methods (Skuballa and Jarodzka, 2022), of which eye tracking – a method to measure where a person looked (Holmqvist et al., 2011; Jarodzka et al., 2021) – has proven to provide particularly interesting insights (Lachner et al., 2016; Jarodzka et al., 2021; König et al., 2022). Eye tracking can directly capture, what a teacher is able to pick up from a video recording of other teachers' authentic classroom situations (Yamamoto and Imai-Matsumura, 2013; Van den Bogert et al., 2014; Wolff et al., 2016) or in an simulated teaching scenario (Stürmer et al., 2017). Research, on teachers professional vision during actual teaching classrooms, however, is still limited (for exceptions, see Cortina et al., 2015; McIntyre et al., 2019; Haataja et al., 2021; Chaudhuri et al., 2022).

Here we present first analyses of eye tracking recordings from a larger data set (Van Driel et al., 2022), where we compared teachers in different career stages, namely, *pre-service* teachers, who are still studying to become a teacher, *beginning* teachers right after having entered the work and field, to *experienced* teachers, who have been working in this field for at least 10 years. Our aim is to gain a deeper understanding of how teachers, in these different stages of their careers, deal with the constant flow of rich and dynamic information reaching them as triggers for (potential) actions to successfully manage a classroom.

2 The role of visual processes in expertise

In the current study we want to take the perspective of the teacher as an expert (Bromme, 2014). Experts are individuals who perform repeatedly better on a set of tasks that are representative for a certain domain (Ericsson et al., 2018). This phenomenon has been widely investigated within specific well-defined domains, such as chess (e.g., Gobet and Charness, 2018; Lane and Chang, 2018) or medicine (e.g., Choudhry et al., 2005; Boshuizen and Schmidt, 2008; Norman et al., 2018). Already early on, it became clear that visual processes play a critical role in the expertise of an individual (e.g., Chase and Simon, 1973; Lesgold et al., 1988; De Groot and Gobet, 1996). The best way to study these visual processes is to use eye tracking (Duchowski, 2003; Holmqvist et al., 2011; Liversedge et al., 2011). The eye tracker is an apparatus that records the eyes of a person looking around, to deduce, which element this person was looking at, for how long, and in which order.

Eye tracking studies showed early on, that the perceptual aspect of expertise in chess are characterized by two features, namely, a larger visual span and more efficient visual processing of individuals with higher expertise (De Groot and Gobet, 1996; Reingold et al., 2001). These two aspects were indicated by fewer fixations and by fixations located in between several chess pieces instead of on individual chess pieces, which indicates that experts encode information from a broader area than individuals with less experience in chess. Similarly, eye tracking studies in medical fields (mainly in radiology) have shown that experts process medical images more efficiently (Krupinski et al., 2013; Van der Gijp et al., 2017; Nodine and Mello-Thoms, 2018) and that they can extract information from the periphery far better than individuals with less experience, indicating a larger visual span (Kundel et al., 1991; Jaarsma et al., 2015; Sheridan and Reingold, 2017).

However, understanding and describing expertise in more ill-structured domains is more difficult to grasp empirically, and a rather recent development in the research field of expertise studies (Boshuizen et al., 2020). One example of such an ill-structured domain where visual processes seem to play a critical role is teaching (Lachner et al., 2016; Jarodzka et al., 2021; Skuballa and Jarodzka, 2022). For instance, the model of Lachner et al. (2016) shows that professional vision of teachers shapes their practical knowledge base, activates their curriculum scripts (i.e., elaborated organized knowledge structures, see Putnam, 1987), which in turn guide teachers' teaching practices, indicating the central role of visual[2] processes in teaching (Lachner et al., 2016). Van Es and Sherin (2002) describe teachers' professional vision as the ability to notice relevant events taking place in the classroom and to interpret them effectively. Over recent years, although being still scarce, eye tracking has increasingly been used to study this professional vision of teachers and offering first pivotal insights while simultaneously raising pressing questions.

The first question that arises is, whether one aspect underlying teaching experience could be the *efficiency in visually processing* a classroom. Such a question has already been studied in eye tracking research extensively under the term 'visual search', where participants look for targets amongst a set of distractors (Wolfe, 1994, 2007; Wolfe and Horowitz, 2017). Usually, either time to find the target or the number of fixations made while searching serves as indicator for efficiency of visual processing. Already early on, eye tracking research found that the number of fixations during task performance is negatively correlated with search efficiency (Goldberg and Kotval, 1999): while a higher number of fixations is indicative of difficulties in interpreting the fixated information (Ehmke and Wilson, 2007), lower number of fixations may signify expertise in a task (Rötting, 2001). Consequently, this research question was pursued widely within expertise research: This phenomenon has been observed across diverse domains, encompassing chip inspectors (Schoonahd et al.,

1 Sometimes this is also referred to as 'visual expertise'. Both terms originate from different research fields, but refer to the same phenomenon and could be used in the case of the current article interchangeably.

2 In educational practice, auditory cues are equally important. This is, however, out of scope of the current study.

1973), inspectors of diverse industrial products (Megaw and Richardson, 1979), chess players (Reingold et al., 2001), and pathologists (Krupinski et al., 2006). This was corroborated by a meta-analysis of different eye tracking measures across expertise studies from diverse domains, in which Gegenfurtner et al. (2011) found that over 43 studies, experts exhibited slightly fewer fixations compared to novices. Notably, contrasting effects have been identified in other contexts, including pilots (Kasarskis et al., 2001), volleyball players (Afonso et al., 2012), and football players (Williams et al., 1994). Contrary, Sheridan and Reingold (2017) found in their literature review that the number of fixations increases with increasing expertise. Hence, we can conclude that, although findings vary broadly, there seems to be an interaction between the experience someone has in a task and the number of fixations during task performance. Recent eye tracking studies hint towards this phenomenon also playing a role in the teaching domain, which differs largely from the earlier mentioned domains of chess or medicine using mainly static stimuli, in that classrooms are highly dynamic and multidimensional (Doyle, 2006). Studies using eye tracking technology while watching video recordings of other teachers' classroom lessons have shown that experienced teachers display shorter fixations, yet more effective monitoring skills (Van den Bogert et al., 2014). Their perception seems more knowledge-driven and less distracted by irrelevant or salient events compared to novices (Wolff et al., 2016). First mobile eye tracking studies of teachers teaching their own classes further substantiate these findings, allowing a more ecological analysis of visual perception in authentic teaching situations (Cortina et al., 2015; Chaudhuri et al., 2022). We can thus conclude that with increasing experience teachers tend to display increasingly more efficient visual processes. It is, however, not entirely clear, yet, how this reflects in concrete eye tracking measures, that is, whether the number of fixations de- or increases when teaching own classrooms.

A second question would be to which extent the *visual span* changes with increasing teaching experience. This phenomenon has been already widely studied with eye tracking in reading research (Rayner, 2009). In the studies most of the text is disguised while only a small part at the current point of focus is visible (so-called gaze-contingent moving-window paradigm: McConkie and Rayner, 1975). In such studies readers have been found to process information from a region extending roughly 3–4 character spaces to the left of the fixation point to about 14–15 spaces to the right (e.g., Rayner et al., 1982; Underwood and McConkie, 1985). However, the perceptual span varies with reading experience. Beginning readers and those with dyslexia, for instance, display smaller spans compared to more skilled readers (Rayner, 1986; Rayner et al., 1989). This has also been studied in expertise in the domains of medicine and chess (for a comprehensive review on expertise differences in the visual span in the domains of medicine and chess, see: Sheridan and Reingold, 2017). It often related to the concept of 'chunking' introduced by Miller (1956), which describes the ability of persons with higher experience in a certain task to group information into larger, meaningful units. Chase and Simon (1973) and Simon and Chase (1973) explored this in the context of chess, suggesting that experts develop advanced memory structures for chunks of chess figures. These memory structures, acquired through extensive practice, allow experts to swiftly encode configurations in terms of larger patterns, emphasizing the significance of professional vision in recognizing overarching patterns rather than discrete features (Gobet and Charness, 2018). The finding that individuals with increasing expertise develop a larger visual span, has been also found in other domains, such as medicine (e.g., Jaarsma et al., 2014; Van der Gijp et al., 2017) or aviation (e.g., Demaio et al., 1978; Kim et al., 2010; Peißl et al., 2018). In teaching, where classrooms are characterized by very dynamic events and many of them happening at the same time, experienced teachers tend to cover more areas of the visual display, demonstrating a broader attentional scope (McIntyre et al., 2019). Beginning teachers, in contrast, may show more focused attention on a small group of students, particularly in feedback provision, reflecting a narrower visual span (Cortina et al., 2015). In addition, we also know that teachers with high levels of experience in teaching have built up complex knowledge structures called 'classroom management' or 'curriculum' scripts that are a similar concept to the above-mentioned chunks (Lachner et al., 2016; Wolff et al., 2021). This would support the idea that the scripts could also enable teachers to develop a larger visual span. This concept has, however, to this day, not been directly, tested for teachers while teaching their own classrooms.

A third question that occurs is whether the *mental effort* teachers experience during teaching changes with higher levels of experience in teaching. Recent reviews have shown that the mental effort experts experience in comparison to novices declines as measured by eye tracking (Gegenfurtner et al., 2011; Peißl et al., 2018; Gil et al., 2022). Mental effort can be captured by means of eye tracking as the duration of fixations (Holmqvist et al., 2011). Eye tracking research has proven repeatedly, that shorter durations of fixations indicate a higher mental effort (Gog et al., 2009; Hyönä, 2010; Van Mierlo et al., 2012; Korbach et al., 2016; Dirkx et al., 2021). Indeed, expertise has been shown to be related to longer fixation durations in diverse domains, such as chess, art (Nodine et al., 1993; Reingold et al., 2001; Reingold and Charness, 2005). However, sometimes the opposite has been found (Gegenfurtner et al., 2011; Sullivan et al., 2011; Jaarsma et al., 2014; Yu et al., 2022) or no effect at all (Lee et al., 2019). Thus, we can assume that the effect of expertise and fixation durations depends to a large extent on the specific task and the stimulus (Bertram et al., 2013). Yet again, it is not trivial to draw conclusions from other areas of expertise research, which mostly study static pictures, to the teaching domain, where the 'stimulus' is highly dynamic and multidimensional with many things happening at the same time (Doyle, 2006). Recently, Chaudhuri et al. (2022) studied with mobile eye tracking how teachers visually processes first-grader classrooms. They found that teachers' fixation durations correlated with students' academic skills and individual support levels, suggesting that student distribution affects how evenly a teacher can allocate their visual attention in the classroom. We do not know yet, however, to which extent teachers' mental effort can be measured by mobile eye tracking when teaching their own classrooms, and how this relates to their level of experience in teaching.

A final question it occurs is weather these above-mentioned concepts are stable over the entire lesson or whether they *change over time*. It is very difficult to draw conclusions from prior research as most eye tracking studies are very short and come nowhere near to the duration of a full lesson. However, there are some indications that visual processes of experienced professionals change over time in a different way than those of less experienced individuals (Jaarsma et al., 2014). It is unclear to which extent this is also true for visual processes of teachers while teaching entire lessons.

3 This study

We can conclude that the exploration of teachers' visual perception through video-based and classroom-based eye tracking studies offers significant insights into the nuanced differences between more and less experienced teachers. These findings may have implications for teacher training and development, emphasizing the importance of fostering efficient visual processes, expanding visual span, or managing mental effort. The research also highlights the potential for further investigation of classroom-based mobile eye tracking to better grasp the complexity of teaching in authentic classrooms. However, eye tracking research while teaching one's own authentic classrooms is still scarce and thus, many questions remain open. Hence, in the current study we investigated three research questions:

1. Do more experienced teachers demonstrate more efficient visual processes compared to their less experienced counterparts?
2. Is the size of the perceptual span influenced by a teacher's amount of teaching experience?
3. Does the mental effort exerted during teaching vary among teachers with different levels of experience?

Furthermore, for each of the three research questions, we explored whether the phase of the lesson influences teachers' visual processing of their classroom.

4 Methods

This submission is part of a larger data set as described in Van Driel et al. (2022). Other publications stemming from this recording, but addressing different data streams, are on interviews with the teachers (Van Driel et al., 2023) and on their signaling of events relevant for classroom management (Van Driel et al., 2021). This research was approved by the ethical committee of the Open University (U2016/08859/FRO).

4.1 Participants and design

Participants were recruited from secondary schools and teacher training institutes in the Netherlands. Three groups of teachers were compared: 22 *preservice* teachers ($M = 22.82$, $SD = 2.65$ years; 55% female) in the third or fourth year of teacher education; 17 *beginning* teachers ($M = 25.82$, $SD = 2.94$ years; 41% female) after their transition to the workplace and having an average of 2.5 years of teaching experience; and 19 *experienced* teachers ($M = 45.00$, $SD = 8.82$ years; 53% female) with at least 10 years of teaching experience in secondary education. Due to the eye tracking nature of the study, only participants with normal vision or corrected-to-normal vision with soft contact lenses were included.

These three groups were eye tracked while teaching their regular classes for one lesson of their choice, which resulted in varying subject, such as geography, history, English, mathematics, etc. [duration: M $(SD) = 44.21$ (5.56) minutes]. From these recordings, three eye tracking measures were derived: *count*, *average duration*, and *total dispersion* of fixations. Additionally, these measures were compared across the *beginning*, *middle* and *end* phase of the lesson. The beginning of the lesson demarked the moment that all pupils were seated and the teacher started the lesson. The lesson ending demarked the moment that the teachers had finished the lesson and pupils started to stand up from their seats to leave the classroom. The time between beginning and ending of the lesson was divided into three phases (equal in duration; M $(SD) = 14.74$ (1.85) minutes) and labeled as beginning, middle and end phase of the lesson.

4.2 Apparatus

Eye tracking data were collected with the SMI 60 Hz eye tracking glasses.[3] These glasses have one camera in the center of the frame directed towards the point of view of the teacher, which is continuously recording the scene towards which the teacher directs their head. Additionally, six infrared lights are built into the frame and directed towards the teacher's eyes. Two infrared cameras, that are built into the lower part of the frame, record the teacher's eyes. Resulting eye tracking data was analyzed with SMI Begaze software (version 3.7.59).

4.3 Procedure

Before the recordings, teachers received information about (i) the nature of this study (i.e., studying the role of professional vision for classroom management in teachers of different experience stages), (ii) requests towards the lessons (i.e., no changes to the sitting arrangements or content of the lessons, but request to include diverse learning activities), and (iii) the procedure of the recording (i.e., eye tracking during lessons, interviewing afterwards). In parallel, parents and students were informed about this study and were asked for consent.

During the recording, teachers wore eye tracking glasses during one entire lesson. To adjust these glasses to each individual person, the experimenter calibrated and validated each teacher with three points and repeated a validation at the end of the lesson. Teachers were instructed to indicate with an inconspicuous hand gesture when they experienced a remarkable classroom management event during teaching. The analysis of these data is already published and out of scope of the current article (Van Driel et al., 2021).

After the recording, teachers were interviewed based on the recorded videos. These data are not part of the current article and are already published elsewhere (Van Driel et al., 2023).

The entire data collection took place in 2017 and 2018.

4.4 Data analysis

The here described recordings resulted in 216.95 GB of eye tracking data. The average tracking ratio was 94.2% ($SD = 3.5$). To ensure sufficient data quality, all recordings below a tracking ratio of 80% were excluded. The remaining recordings were visually screened for substantial data loss or off-set of the recorded teachers' visual focus. Furthermore, we decided to perform the analysis on classes where pupils were sitting in rows and this resulted in a final dataset of

3 www.smivision.com, discontinued.

45 teachers of which 16 preservice teachers, 14 beginning teachers and 15 experienced teachers. Teachers, in whose lessons students were sitting in other sitting arrangements (e.g., arts lessons, where students were sitting in groups) were excluded for the current eye tracking analyses to ensure a somewhat comparable visual setting.

Next, eye movement events were detected within raw data streams with SMI's algorithm for mobile eye tracking data. We applied settings to define saccades of below 100°/s or above 8°/s and a minimal skewness of 5 and fixations of at least 50 ms duration. Three measures were derived from these fixations: their total count, their average duration, and their dispersion.

We used ANOVAs with an $\alpha < 0.05$ to test whether the different eye movement metrics differed according to expertise level of the teachers. In a next step, we used mixed-effects models to examine whether the different eye movement metrics (i.e., count, average duration and dispersion) differed according to lesson phase (beginning, middle, end) and expertise level (preservice, beginner and experienced). The analysis was carried out in R and Rstudio (version 2023.03.1). For each eye movement measure, a separate mixed model was estimated with the eye movement measure as dependent variable, with expertise level, lesson phase and their interaction as fixed effects and with participant as random effect using the lme4 package (version 1.1–33; Bates et al., 2015). The lmerTest package was used to obtain *p*-values (version 3.1–3; Kuznetsova et al., 2017). The performance package was utilized to obtain the marginal and conditional R2 of the models (version 0.10.4; Ludecke et al., 2021). Additional *post hoc* comparisons were performed with the emmeans package (version 1.8.6, Lenth, 2022).

5 Results

Means and standard deviations can be found in Table 1. The output of the mixed effects models can be found in Table 2.

5.1 Efficiency of visual processing

No significant differences were found for count of fixations during the overall lesson, $F(2, 42) = 0.03$, $p = 0.97$, $\eta^2 = 0.001$. This indicates that there are no overall advantages in efficiency of experience on visual processes. Count of fixation did also not differ between preservice, beginning and experienced teachers during the different lesson phases (Table 3). During the end phase of the lesson, preservice teachers show a marginally significant increase in fixation counts compared to the beginning phase ($p = 0.06$, Table 4). 82% of the variance in fixation count was explained by both the random and fixed effects and 1% of the variance was explained by the fixed effects (i.e., expertise and lesson phase) only. For means and standard deviations see Figure 1 and Table 2.

5.2 Perceptual span

There was no significant effect of expertise on the total dispersion of fixations, $F(2, 42) = 0.64$, $p = 0.53$, $\eta^2 = 0.03$. Looking at the different phases of the lesson, results show that experienced teachers have a larger visual span at the beginning of the lesson compared to the end of the lesson (Table 3, $p = 0.04$). 76% of the variance in average fixation dispersion was explained by the full model, while 5% was explained by expertise level and lesson phase only. For means and standard deviations see Figure 2 and Table 2.

5.3 Mental effort

There was no significant effect of expertise on the average duration of fixations, $F(2, 42) = 1.24$, $p = 0.30$, $\eta^2 = 0.06$. Looking further to the different phases of the lesson, results show again a changing pattern for preservice teachers (Figure 3). Preservice teachers show a marginally significant decrease towards the end phase of the lesson compared to the beginning ($p < 0.08$) and middle phase ($p < 0.08$) (Refer to Table 4). This indicates that preservice teachers experience less mental effort during the end phase of the lesson. 79% of the variance in average duration of fixations was explained by the full model and 5% of the variance was explained by the fixed effects only (i.e., expertise and lesson phase) (Refer to Table 2).

6 Discussion

6.1 Preservice teachers struggle towards the end of the lesson

The present study aimed to investigate the efficiency of teachers' visual processing in terms of the *number of fixations* made, depending on their level of experience (Research Question 1). Our findings did not reveal any significant differences in the count of fixations during the overall lesson among preservice, beginning, and experienced teachers. This suggests that, overall, there are no advantages in visual processing efficiency based on teaching experience. These results contradict previous findings in other domains, which were, however, mixed. It is possible that the nature of the teaching task and the complexity of classroom environments contribute to the different outcomes observed in our study. It is in line though, with our previous analyses of other data sources from this study, where we found no differences between the number of challenging classroom situations identified by all three teacher groups (Van Driel et al., 2021) nor in how they talk about these situations (Van Driel et al., 2023). Another study on teachers' efficiency of visual processes did find differences between more and less experienced teachers: McIntyre et al. (2017) found that expert teachers have more efficient visual processes, with a focus on student-centeredness, compared to novices. Their gaze is more often directed at students, indicating a priority for student engagement and feedback. These researchers, however, focused in their study primarily on student-teacher interactions within two different cultural contexts (Hong Kong vs. UK), which might have contributed to coming to different conclusions than we do in our current study. In a more comparable cultural context (i.e., German) Stürmer et al. (2017) found that preservice teachers face challenges in maintaining consistent attention in classroom settings, frequently shifting their focus and possibly not processing relevant classroom information as efficiently as their experienced counterparts. However, they did not compare these preservice teachers to more experienced counterparts.

Additionally, the count of fixations did not differ between the different lesson phases for preservice, beginning, and experienced teachers. This implies that the visual processing patterns remained

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TABLE 1 Means and standard deviations.

	Fixation count			Fixation average duration			Fixation average dispersion		
	Preservice	Beginner	Experienced	Preservice	Beginner	Experienced	Preservice	Beginner	Experienced
Beginning	2.27 (0.31)	2.25 (0.30)	2.23 (0.29)	311.30 (55.85)	335.39 (48.58)	332.03 (51.97)	113.87 (29.35)	123.53 (32.22)	128.97 (33.20)
Middle	2.31 (0.33)	2.23 (0.37)	2.24 (0.29)	310.71 (43.87)	342.25 (61.25)	330.51 (52.40)	104.46 (26.33)	119.38 (29.57)	117.30 (34.16)
End	2.35 (0.30)	2.23 (0.33)	2.24 (0.23)	297.49 (38.38)	336.18 (56.36)	329.68 (44.50)	106.15 (24.09)	111.17 (23.26)	117.41 (34.84)
Overall	2.26 (0.28)	2.24 (0.32)	2.27 (0.23)	310.53 (42.21)	335.56 (49.40)	322.45 (38.32)	108.90 (24.43)	117.36 (26.66)	119.73 (32.36)

consistent throughout the lesson, regardless of the teachers' experience levels. However, a marginally significant increase in fixation counts was observed for preservice teachers during the end phase of the lesson compared to the beginning phase. This finding suggests that preservice teachers become less efficient during the later stages of the lesson. This might be the case, because they either get more accommodated to teaching their lesson or because they must speed up as they might be running short on lesson time. Another possible, albeit related, explanation would be that they experience more stress and mental effort resulting in faster visual processes. We cannot exclude other potential factors, such as specific behaviors of the students, the taught subject or the time of the day, could have influenced their visual processing as well. However, such factors should not have varied systematically within one teacher group only.

Regarding Research Question 2, our results suggest that while there is no overarching effect of teaching experience on the overall dispersion of fixations, there exists a nuanced interplay between experience and specific lesson phases. Specifically, experienced teachers appear to exhibit a broader *visual span* at the lesson's commencement, which narrows as the lesson progresses. This finding is particularly interesting when contextualized against prior research. Drawing from the foundational literature, the modulation of visual span with experience is a well-documented phenomenon in various domains, from reading to chess. In teaching, previous studies have highlighted experienced teachers demonstrating a wider attentional scope, juxtaposed against beginning teachers' more concentrated attention, especially during feedback provision (Cortina et al., 2015; McIntyre et al., 2019). This notion finds resonance in the concept of 'chunking', where experts, through extended practice, develop an ability to process larger, overarching patterns rather than isolated features (Chase and Simon, 1973; Gobet and Charness, 2018). The theoretical concept of 'classroom management scripts' in teaching, similar to 'chunks,' suggests that teachers with advanced experience cultivate intricate knowledge structures, potentially enabling them to encompass a more expansive visual span (Wolff et al., 2021). However, in the current study, we did not assess to which extend the experienced teacher group indeed possessed higher levels of expertise in terms of classroom management. Our sample could have included experienced teachers with varying levels of expertise in classroom management, which in turn, would have limited the ability of chunking of part of this group and thus tainted our results. Still, our findings are in line with other research, such as by Stürmer et al. (2017), who found that preservice teachers exhibit challenges in evenly distributing their attention among students. These findings are corroborated by two other studies explicitly focusing on teachers with different experience levels: Cortina et al. (2015) suggest that while novice teachers might overly focus on specific students, especially when giving feedback, experienced teachers tend to maintain a broader attention span, distributing their gaze more evenly across the classroom, even when providing feedback. This ability to manage attention might be a key factor in their more effective classroom management. McIntyre et al. (2017) showed that experienced teachers demonstrate a strong student-centered approach in their attention distribution, with a consistent and flexible gaze towards students. Novices, in contrast, show a higher tendency to be distracted and have a more variable approach in their communicative gaze. Given this backdrop, our findings underscore the dynamic nature of

TABLE 2 Output of the mixed effects models.

	Fixation count				Fixation duration average				Fixation dispersion average			
Random effects	Variance	*SD*			Variance	*SD*			Variance	*SD*		
Participant	0.07	0.27			1752.7	41.87			701.30	26.48		
Residual	0.02	0.13			498.1	22.32			232.50	15.25		
Fixed effects	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
Intercept	2.27	0.08	28.52	<0.001	332.05	12.68	26.19	<0.001	121.61	8.17	14.89	<0.001
Middle phase	−0.04	0.05	−0.89	0.38	9.32	8.44	1.11	0.27	−2.85	5.76	−0.50	0.62
End phase	−0.04	0.05	−0.74	0.46	3.18	8.44	0.38	0.71	−9.69	5.76	−1.68	0.10
Experienced	0.009	0.11	−0.08	0.94	−10.92	17.63	−0.62	0.54	6.79	11.36	0.60	0.55
Student	−0.05	0.11	−0.43	0.67	−14.69	17.36	−0.85	0.40	−6.95	11.18	−0.62	0.54
Middle phase*experienced	0.02	0.07	0.23	0.82	−5.10	11.73	−0.44	0.66	−8.66	8.01	−1.08	0.28
End phase*experienced	0.03	0.07	0.44	0.66	−2.07	11.73	−0.18	0.86	−4.25	8.01	−0.53	0.60
Middle phase*student	0.05	0.07	0.83	0.41	−9.05	11.55	−0.78	0.44	−4.76	7.89	−0.60	0.55
End phase*student	0.14	0.07	2.12	0.04	−20.25	11.55	−1.75	0.08	1.24	7.89	0.16	0.88
Model fit	Marginal R^2		Conditional R^2		Marginal R^2		Conditional R^2		Marginal R^2		Conditional R^2	
	0.01		0.82		0.05		0.79		0.05		0.76	

TABLE 3 Multiple comparisons of means within lesson phases for experience level.

	Fixation count				Fixation duration average				Fixation dispersion average			
	β	SE	*t*	*p*	*β*	SE	t	*p*	*β*	SE	*t*	*p*
Beginning												
Beginner – experienced	−0.009	0.11	−0.08	0.99	10.92	17.6	0.62	0.81	−6.79	11.4	−0.60	0.82
Beginner – preservice	0.05	0.11	0.43	0.90	14.69	17.4	0.85	0.68	6.95	11.2	0.62	0.81
Experienced – preservice	0.06	0.11	0.52	0.86	3.77	17.1	0.22	0.97	13.74	11.0	1.25	0.43
Middle												
Beginner – experienced	−0.02	0.11	−0.22	0.97	16.02	17.6	0.91	0.64	1.87	11.4	0.17	0.99
Beginner – preservice	−0.008	0.11	−0.07	0.99	23.75	17.4	1.37	0.36	11.71	11.2	1.05	0.55
Experienced – preservice	0.02	0.11	0.15	0.99	7.73	17.1	0.45	0.89	9.84	11.0	0.90	0.65
End												
Beginner – experienced	−0.04	0.11	−0.35	0.94	12.99	17.6	0.74	0.74	−2.55	11.4	−0.22	0.97
Beginner – preservice	−0.09	0.11	.-85	0.68	34.95	17.4	2.01	0.12	5.71	11.2	0.51	0.87
Experienced – preservice	−0.05	0.11	−0.50	0.87	21.95	17.1	1.29	0.41	8.26	11.0	0.75	0.73

the visual span in teaching. The broader visual attention observed in experienced teachers during a lesson's early phases could reflect their ability to quickly assimilate and process the classroom environment, drawing from their extensive 'management scripts.' However, as the lesson progresses, their attention might become more selective, reflecting a strategic shift in focus based on classroom needs. This evolving pattern of attention underscores the richness of the teaching process and sets the stage for deeper exploration into understanding the multifaceted influences shaping teachers' visual spans across different classroom scenarios.

According to the third research question, the current study sought to determine whether *the mental effort*, as indicated by the duration of fixations, experienced by teachers during teaching varied with their level of teaching experience. Eye tracking research has shown that the durations of fixations is an indicator for mental effort (e.g., Reingold and Charness, 2005; Van Mierlo et al., 2012; Korbach et al., 2016). However, the concrete relationship in relation to expertise has proven inconsistent across studies (e.g., Gegenfurtner et al., 2011; Jaarsma et al., 2014; Yu et al., 2022). The underlying suggestion is that the connection between expertise and fixation durations could be contingent on the specifics of the task and stimuli (Bertram et al., 2013). In our study's findings, expertise did not yield a significant impact on the average duration of fixations. Interestingly, the data reveals a

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TABLE 4 Multiple comparisons of means within experience level for different lesson phases.

	Fixation count				Fixation duration average				Fixation dispersion average			
	β	*SE*	*t*	*p*	*β*	*SE*	t	*p*	*β*	*SE*	*t*	*p*
Preservice												
Beginning – Middle	−0.01	0.05	−0.27	0.96	−0.27	7.89	−0.03	0.99	7.61	5.39	1.41	0.34
Beginning – End	−0.10	0.05	−2.31	0.06	17.07	7.89	2.16	0.08	8.45	5.39	1.57	0.27
Middle - End	−0.09	0.05	−2.05	0.11	17.34	7.89	2.20	0.08	0.84	5.39	0.16	0.99
Beginner												
Beginning – Middle	0.04	0.05	0.89	0.65	−4.22	8.15	−0.52	0.86	2.85	5.76	0.50	0.87
Beginning – End	0.04	0.05	0.74	0.74	−1.11	8.15	−0.14	0.99	9.69	5.76	1.68	0.22
Middle - End	−0.007	0.05	−0.15	0.99	3.11	8.15	0.38	0.92	6.84	5.76	1.19	0.46
Experienced												
Beginning – Middle	0.03	0.05	0.59	0.83	−4.22	8.15	−0.52	0.86	11.52	5.57	2.07	0.10
Beginning – End	0.006	0.05	0.13	0.99	−1.11	8.15	−0.14	0.99	13.94	5.57	2.50	0.04
Middle - End	−0.02	0.05	−0.47	0.89	3.11	8.15	0.38	0.92	2.42	5.57	0.44	0.90

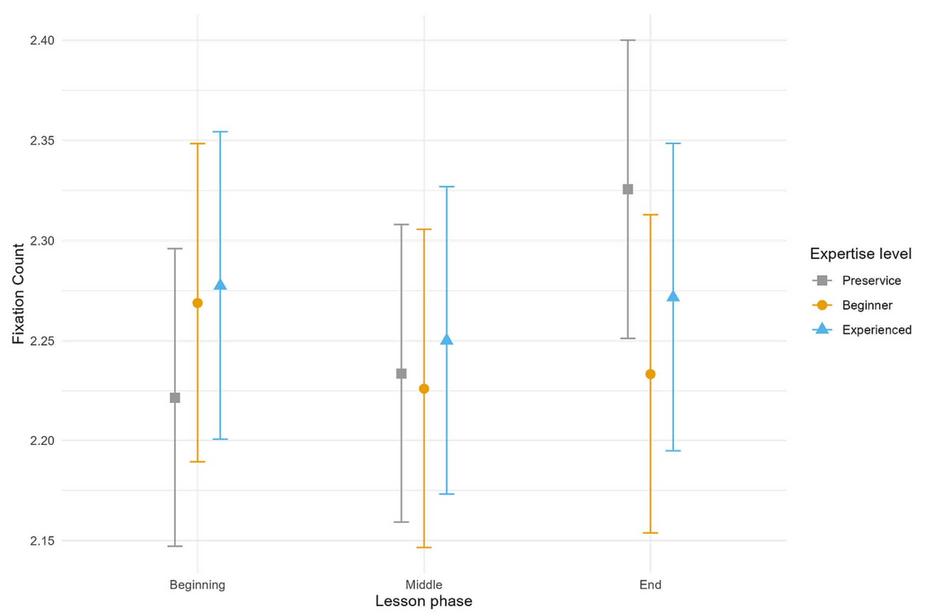

FIGURE 1
Interaction effect of experience level and lesson phase for efficiency of visual processing.

subtle distinction when observing preservice teachers. They manifested a trend towards shorter fixation durations, especially as lessons ended. This trend hints at an increased mental effort for preservice teachers during the concluding segments of lessons. The reasoning might be that preservice teachers still struggle with many aspects of teaching throughout a lesson, such as adhering to a lesson plan, which in turn can result in them experiencing time pressure and stress towards the end of the lesson, which is here reflected in higher mental effort. These insights provide a glimpse into the multifaceted nature of teaching and its cognitive demands, emphasizing the importance of situational context in determining how experience impacts mental effort within the teaching environment.

6.2 Limitations and future research

It is important to note that our results should be interpreted within the limitations of the study. First, the sample size was relatively small, which may have restricted the statistical power to detect subtle differences. Future studies with larger sample sizes could provide more robust insights into the relationship between teaching experience and professional vision. Second, the study focused solely on the count, duration, and dispersion of fixations as an indicator of visual processing efficiency, size of visual span, and mental effort. This approach was chosen (a) because these measures were most appropriate to address our current research questions and (b) due to the sheer amount of data (approx. 217 GB or 45 h of individual

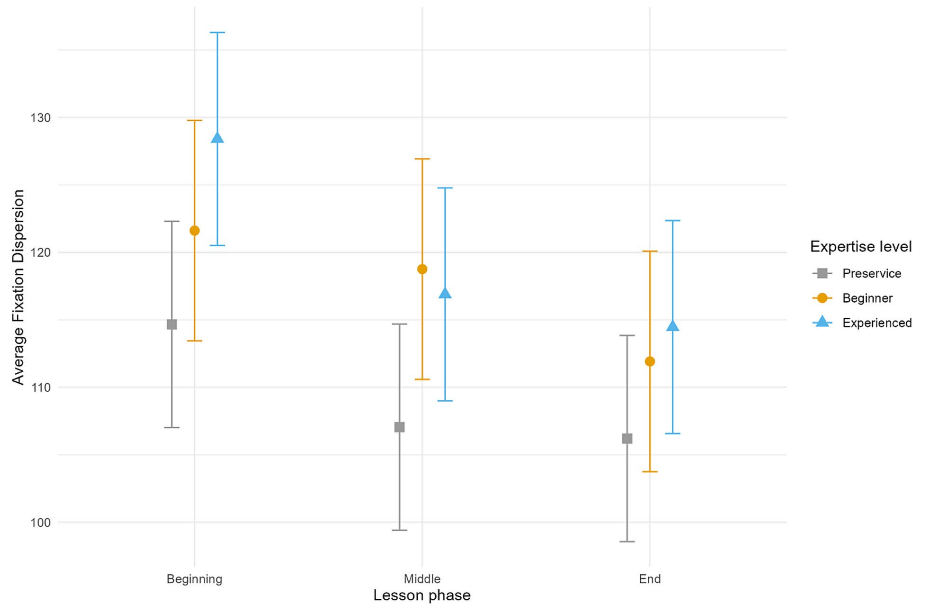

FIGURE 2
Interaction effect of experience level and lesson phase for visual span.

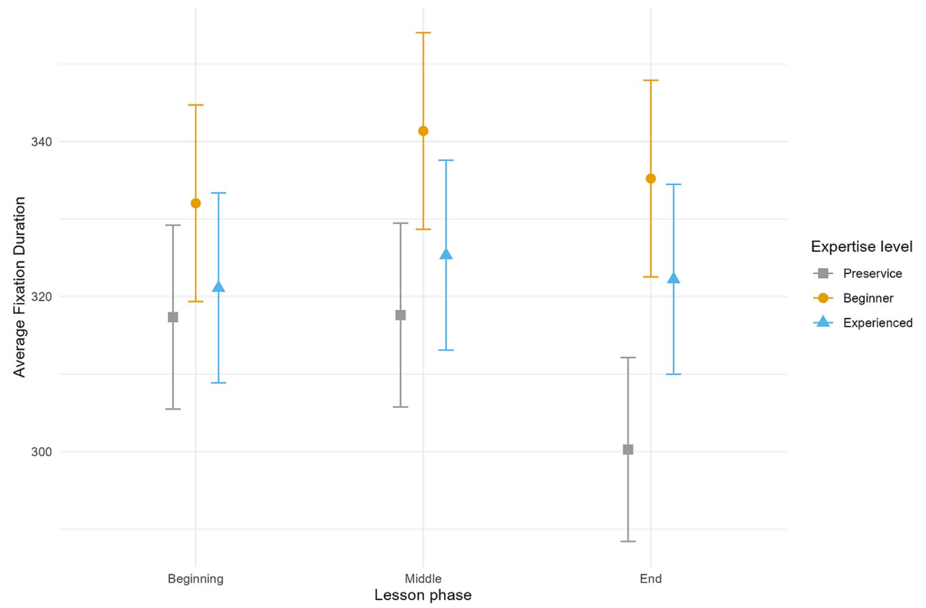

FIGURE 3
Interaction effect of experience level and lesson phase for mental effort.

videos). Other eye tracking measures, such as scan patterns or analyses of specific areas that teachers did or did not look at, could provide a more comprehensive understanding of teachers' visual processing strategies. To be feasible, such analyses require, however, further methodological developments, for instance, on the side of machine learning, or very clear focus on specific moments in the lessons, which analyses as presented in the current study, can provide. Third, we studied teacher groups according to their years of experience in teaching classes. It must be noted, however, that this is not necessarily the same as studying different levels of expertise. Different levels of expertise assume different amounts of knowledge and skills and in particular a clear difference in the advancement of organized knowledge structures in long-term memory (Bromme, 2014; Lachner et al., 2016; Ericsson et al., 2018; Wolff et al., 2021). We can safely assume that preservice teachers have less knowledge and skills compared to the other two groups and even assume that beginning teachers, possess limited experience and thus skills compared to their more experienced counterparts. Where we fall short, however, is the 'experienced' teacher group. Although we know that they have taught for at least 10 years, we cannot guarantee that this made them experts in classroom management. This group could consist of experienced teachers with varying degrees of expertise in classroom management. This fact unfortunately, limits the degree to which we can draw conclusions from our research to the field of expertise studies. Future research should incorporate an assessment of each teacher's level of expertise, for instance, by standardized video-tests (Seidel et al., 2010) or by observing and scoring their classroom management during teaching (Wubbels et al., 2022).

The conflicting findings from previous research and our study highlight the need for further investigation into the relationship between teaching expertise and visual processing. Future research could explore additional factors that may influence visual processing efficiency in teaching, such as pedagogical approaches, subject matter expertise, or classroom management skills. Moreover, incorporating qualitative methods, such as interviews or think-aloud protocols, could provide valuable insights into the cognitive processes underlying teachers' visual attention and information processing.

7 Conclusion

In conclusion, our study did not find overall advantages in the efficiency of teachers' visual processing based on their level of experience alone. Instead, we found an interplay of teaching experience and phase of the lesson indicating that all teachers start off in the lesson in a similar way, but particularly pre-service teachers seem to experience some sort of difficulties with their classroom management as the lesson goes on. Given that classroom management has shown to directly influence pupils' learning and well being (Hattie, 2009), this difficulty could be targeted in teacher training specifically. Eye tracking could serve as a valuable additional information source (next to self-reports and observations) to identify exactly where pre-service teachers face challenges when ending a lesson. For instance, teacher trainers could use such recordings of the individual pre-service teachers to better understand the perspective of the pre-service teacher and provide illustrative feedback on either missed events or incorrectly interpreted ones. These findings contribute to the existing body of literature on experience and visual search, emphasizing the complexity of the relationship in the context of teaching. Further research is needed to unravel the intricate interactions between teaching expertise, visual attention, and cognitive processes to enhance our understanding of effective teaching practices.

Data availability statement

The datasets for this study can be found here: https://osf.io/2ach4/?view_only=6cd13dbe667846babd7f1bd141468df6.

Ethics statement

The studies involving humans were approved by the Research Ethics Committee of the Open Universiteit Nederland (cETO) (reference number U2016/08859/FRO). 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

HJ: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft. SD: Conceptualization, Investigation, Methodology, Writing – review & editing. LC: Data curation, Formal analysis, Writing – review & editing. FC: Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision.

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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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Pre-service and in-service teachers' professional vision depending on the video perspective—What teacher gaze and verbal reports can tell us

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Teachers are involved in complex teaching situations every day; thus, they must understand what to pay attention to in the classroom, how this information is to be interpreted, and which teaching decisions become necessary as a result. In educational research, these competencies are known as "professional vision." The purpose of this exploratory study was to examine the professional vision of pre-service teachers (PTs) and in-service teachers (ITs) by investigating whether the groups differ in what they notice and how they reason about videotaped classroom events; whether the perspective of the video viewed influences their noticing and reasoning; and to what extent their gaze behavior differs from their verbal statements. Thirty-one PTs and twenty ITs watched a video clip of authentic teaching, shot from different perspectives, and their visual focus of attention was recorded using a remote eye-tracker. Subsequently, participants reported in an interview what they had noticed. The triangulated data show that the gaze behavior of the PTs and ITs did not differ, but the content of their verbal statements did. Depending on the video perspective, participants focused on different subjects, but this difference was not reflected in the verbal data. Thus, the gaze behavior and verbal statements are not consistent. The findings indicate that considering multiple sources and types of data is beneficial to explore professional vision and that further research is needed to understand the concept in depth.

KEYWORDS

teacher education, professional vision, eye-tracking, mixed-methods approach, in-service and pre-service teachers, video perspectives

Introduction

Teaching is a complex task. Teachers have to manage teaching and learning processes while monitoring an entire school class. They must continuously assess students' learning and performance and make teaching decisions (Kohler et al., 2008). A teacher's professional competence therefore involves understanding what to pay attention to in the classroom and how to interpret that information and making rapid instructional decisions accordingly. These competencies are referred to as "professional vision" in educational research (Keller et al., 2022).

Professional vision encompasses different sub-processes. Despite some variation in definitions, it is widely agreed that professional vision involves two main processes: "noticing" and "knowledge-based reasoning" (Grub et al., 2020; Muhonen et al., 2023). "Noticing" is the ability to focus attention on classroom events that are relevant to teaching and learning, while "knowledge-based reasoning" describes the ability to apply professional knowledge about teaching and learning to interpret these events and draw appropriate conclusions (Grub et al., 2020; Kosel et al., 2021).

Videotaped examples of teaching as stimuli and verbal data of viewers have often been used to study professional vision (Seidel and Thiel, 2017). In such procedures, the participants are asked to comment on what they have seen in a video, and their statements are evaluated qualitatively (Seidel and Stürmer, 2014; Weyers et al., 2023). Recent technical developments have enabled the collection of not only verbal data but also the gaze behavior of participants while they watch videos. Eye-tracking technology allows the investigation of the visual attention of individuals watching videotaped teaching (e.g., with remote eye-tracking) or being active in the classroom due to mobile eye-tracking. However, eye-tracking can only map teachers' professional vision in terms of noticing. Gaze data alone are therefore insufficient to describe teachers' professional vision. Additional data are needed, such as verbal data related to observing teaching, to capture teachers' knowledge-based reasoning behind their gaze behavior (Muhonen et al., 2023). This type of mixed-methods design is seen as promising for studying professional vision and gaining further insights into its nature and characteristics (Godfroid et al., 2020; Wyss et al., 2020). Corresponding studies are, however, still rare (Minarikova et al., 2021), and it remains largely unclear to what extent the gaze behavior is reflected in verbal statements.

Professional vision is seen as a competence that evolves with the development of expertise (Gegenfurtner et al., 2020). Through deliberate practice, the initially isolated and explicit knowledge base of novices is restructured and develops into more integrated and organized scripts (Stahnke and Blömeke, 2021). This knowledge likely influences experienced teachers' ability to search specifically and efficiently for relevant clues in teaching situations. It allows them to focus on the important issues in a given situation and use their knowledge to situate and interpret these situations. In contrast, novice teachers have not acquired the knowledge that enables efficient and effective cognitive processing of classroom situations (Wolff et al., 2016) and they therefore tend to focus on superficial aspects of teaching situations that have little relevance to teaching and learning processes (Meschede et al., 2017). Studies investigating professional vision have found differences between experienced and novice teachers in both verbal and visual data. The main findings are briefly outlined below.

Analyses of verbal data reveal that novice teachers describe teaching situations in rather limited and naïve terms, whereas experienced teachers are better able to draw on their conceptual knowledge to situate, describe, and interpret situations (Stürmer et al., 2013). In terms of content, novice teachers tend to focus more on the teacher's actions and activities than on the students and concentrate more on pedagogy than on the subject and subject didactics. They also tend to evaluate rather than interpret and make general assertions rather than refer to specific events (Simpson and Vondrová, 2019).

Studies using eye-tracking technology are concerned with investigating teachers' visual focus of attention. Accordingly, visual data are of interest. Human eye movements are generally controlled by two processes. Bottom-up attention is driven by salient features of the target (e.g., a colorful garment or the restless behavior of a student); top-down attention is driven by task-related plans, current goals, and intentions derived from professional knowledge (Goldberg et al., 2021; Kosel et al., 2021). For novice teachers, bottom-up processes are more likely to be active. They are not yet able to effectively process all incoming information and to decide which visual cues are most important and are thus more likely to be distracted by salient features. Their gaze behavior may therefore differ from that of experienced teachers (Goldberg et al., 2021). Results from eye-tracking studies could indeed reveal that experienced teachers fixated more areas of classroom events, revisited them more often, and fixated more areas with relevant information (i.e., areas where activities relevant to learning were visible). Novice teachers, in contrast, tended to skip areas in their field of view and more often failed to identify relevant classroom events in standardized video sequences (Keller et al., 2022).

As visual perception is important in professional vision, the camera perspective could have an influence when working with classroom videos, as confirmed by individual studies. Paulicke et al. (2019), for instance, showed that the camera angle influenced observer ratings. The raters assessed the teaching quality of videos recorded with pupil cameras (video recordings with particularly wide-angle cameras and audio recordings of groups of pupils) as, on average, lower than those recorded with teacher and overview cameras. In a study by Cortina et al. (2018), pre-service teachers recorded their teaching with mobile eye-tracking devices. Their analysis of verbal data from the video-stimulated recalls revealed that the participants' comments focused more often on the learners than on the teacher, compared to findings from comparable studies in which participants annotated their own videos, recorded from the observer's perspective. However, to the best of our knowledge, no studies have explicitly investigated different camera perspectives in the context of professional vision.

The results available to date show differences in the professional vision of novice and experienced teachers in both noticing and reasoning about teaching. However, as few studies have explicitly conducted expert–novice comparisons, the evidence base is limited (König et al., 2022). Moreover, little research has investigated the effect of the camera perspective (Gold and Windscheid, 2020). This exploratory project aims to contribute to the identified research gap by investigating the professional vision of pre-service (PTs) and in-service teachers (ITs). Two methods of data collection were used for this purpose. While watching video clips of teaching, the participants' gaze behavior was recorded using remote eye-tracking; afterward, the participants were interviewed about their observations of the previously watched video clip. Accordingly, the potential of mixed methods to study professional vision was also exploited in the study. Due to the exploratory nature of the study, no hypotheses were formulated. The following research questions (RQs) were addressed:

RQ1: Do PTs and ITs differ in the aspects of the classroom they observe and describe?
RQ2: Does the video perspective influence what participants observe and describe about the classroom?
RQ3: To what extent do gaze behavior and verbal reports differ?

Methods

Study design and procedure

To answer the RQs, a mixed-methods design was chosen, following Wyss et al. (2020). The data were collected between November and December 2021 by three trained project members. First, PTs and ITs watched a 90-s video clip of authentic teaching. The clip was selected by two project members. They independently searched three classroom videos on three subjects, which had been recorded in a previous project, for short sequences showing as many relevant aspects of teaching and learning as possible. The individually selected sequences were compared, and a collective selection was made. The sequence shows a German lesson in which the teacher interrupts the class during a student-centered work phase because she notices that the assignment is not clear to the learners. The video clip thus contains aspects of assignment, individual learning support, omnipresence, attention control, and exhortation.

The clip was recorded from three perspectives. Two recordings show the observer's perspective and were taken with static cameras, one at the back of the room and one at the front (alongside the blackboard). The third recording shows the perspective of the teacher wearing eye-tracking glasses (Tobii Pro Glasses 2) during the lesson. The PTs and ITs were randomly assigned to one of the three perspectives. For data collection, the PTs and ITs each watched one of the clips on a laptop [HP ZBook 15 G4, display: 39.62 cm (15.6 inches), resolution: 1920 × 1080], and their gaze behavior was recorded with a remote eye-tracker (Tobii Pro Nano, 60 HZ, nine-point calibration). Immediately after the participants had watched the video clip, an oral follow-up interview of about 20 min followed (cf. Wyss et al., 2020). First, the participants were asked to report on what they had noticed in the video that they had just watched. The corresponding initial question was "What did you notice?" The participants had complete freedom to respond, and their statements were used for the analyses reported in this study. The interviews were audio-recorded and transcribed at an intermediate level of annotation.

Sample

The sample consisted of 31 PTs and 20 ITs from five lower secondary schools hosting teacher trainees from the FHNW School of Education who voluntarily participated. The PTs and ITs were randomly assigned to one of three video perspectives resulting in six test groups. Due to technical problems with the calibration and recording of the remote eye-tracker, data from 12 participants could not be used. Unfortunately, the technical problems (mainly problems with the calibration of the eye-tracking device) occurred disproportionately across the groups. In one test group, data from only three participants could be used. To have six groups of equal size, we chose the smallest group size as a reference and randomly selected three individuals from all other groups. Thus, the final sample consisted of 18 individuals, nine PTs and nine ITs (see Figure 1). Five PTs were women; four were men. They were studying in their third semester at the FHNW School of Education and were, on average, 26.11 years old (SD = 7.99). Three ITs were women; six were men. They were, on average, 47.56 years old (SD = 9.61). Three ITs had 6–20 years of teaching experience, three 21–25 years, one 26–30 years, and two 31–35 years.

Data analyses

Video codings

As the video recordings have a dynamic image, an automated evaluation of remote eye-tracking data using Tobii's analysis software was not reasonably possible. As with previous studies (e.g., McIntyre and Foulsham, 2018; Telgmann and Müller, 2023), data were therefore analyzed manually by consensus between two trained project members. While the videos were played at slow speed (0.12), the coders assigned each fixation to one predefined area of interest (AOI). The three AOIs, "teacher," "student," and "learning material," were defined based on Cortina et al. (2018). The code "other" was used for all fixations outside the three AOIs (e.g., fixation on the window). If a fixation could not be clearly assigned to one of the AOIs or "other" (e.g., fixation on student and learning material at the same time), the coders inferred from the gaze progression what the person was looking at. If this was not possible, the code "undefined" was assigned. Accordingly, five codes were applied: "teacher," "student," "learning material," "other," and "undefined." Due to the perspective of the eye-tracking video, the teacher is not visible in this video. However, the teacher's arms and hands often appear in the video. If these were fixated by the participants, the code "teacher" was assigned to this video too.

The number of each code was counted for every participant. The proportion of each code in relation to the total number of codes per participant was then determined. These values, i.e., the relative numbers (percentages), are used in the analyses.

Interview codings

The verbal statements were analyzed using qualitative content analysis (Kuckartz, 2012) in MAXQDA using individual themes as the unit for analysis, with the smallest unit being a sentence part. Statements with multiple meanings were assigned different codes. The same code was used several times by being assigned to all corresponding statements. Coding was done by consensus (Hopf and Schmidt, 1993). The same text was coded by two project members, and the coding decisions were discussed afterward. This led to a specification of the category system and ensured the quality of the coding process (Kuckartz and Rädiker, 2022). Due to the small number of cases, all data were coded as described. Following Muhonen et al. (2023), the coding system consists of two main categories "description" and "explanation." The four codes for the category "description" were adopted (like the video codings) from Cortina et al. (2018): "teacher," "student," "learning material," and "no focus." Statements describing activities and behavior of actors in the classroom (e.g., the students are working; there was a lively exchange) were coded "teacher" or "student." The code "learning material" was only assigned if the material was described that the class used in the video clip. Other aspects that were mentioned but

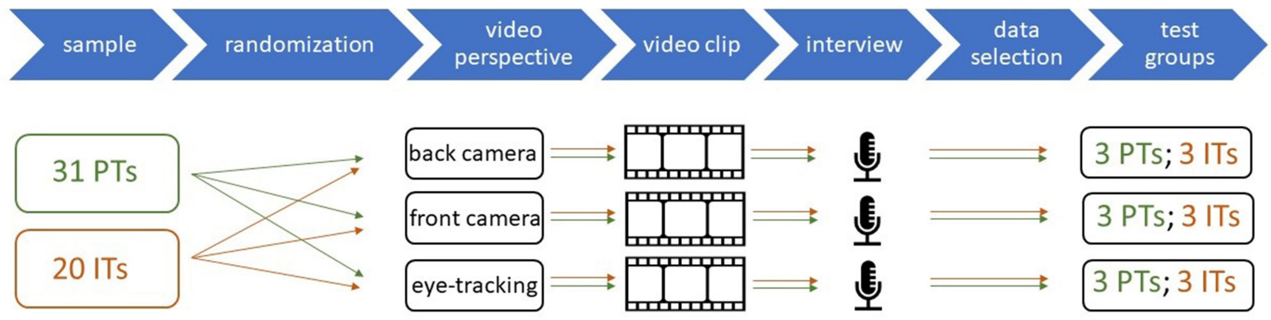

FIGURE 1
Overview of data collection.

not specifically related to the teaching and learning process, (e.g., number of students or appearance of the classroom or individuals) were coded "no focus." The two main categories and four codes were determined deductively.

Videos enhance teachers' capacity to identify pertinent events of teaching as they provide the opportunity to deliberately focus on student learning (Gaudin and Chaliès, 2015). According to Cortina et al. (2018), eye-tracking videos are beneficial for shifting the focus of the analysis to the students. The code "student" was therefore of particular interest and examined more closely in terms of content. Statements about students' actions were inductively categorized in subcodes (e.g., "students are working"; "students are looking at the tablet"). In total, 13 subcodes were defined.

Statements that went beyond mere description and contained conjectures, judgments, further thoughts, and alternative actions were coded with the category "explanation" (Muhonen et al., 2023) and, again, categorized inductively. Among the topics found were alternative actions, evaluations of the teacher's actions, speculations about the teacher's possible thoughts and intentions, and comments on the students' learning level. Ten subcodes were defined inductively. Analogous to the video codings, for each person, the number of times each code was given was counted and the proportion of each code in relation to the total number of codes given per person (relative number) was determined.

Analyses regarding the research questions

To answer RQ1, data from PTs and ITs were contrasted regarding the number of fixations and interview statements using an independent-sample *t*-test. Moreover, the codings of the verbal data of the PTs and ITs were compared by means of cross-tabulations (see Supplementary Tables 1–3).

Regarding RQ2, differences in the number of fixations and interview statements among the three perspectives were analyzed using an ANOVA or the Kruskal–Wallis test if the assumptions for parametric analyses were not met. The codings of the verbal data regarding the three video perspectives were compared by means of cross-tabulations (see Supplementary Tables 4, 5).

Considering RQ3, the content focus of the visual data (fixations) and verbal data (interview statements) were compared using repeated-measures ANOVA or Friedman's test if the assumptions for parametric analyses were not met. Moreover, the visual fixations were contrasted with the interview statements using a paired sample *t*-test.

Data analyses

Comparison of ITs and PTs (RQ1)

PTs and ITs did not differ in how often (relative number) they verbally described or visually fixated on the teacher, students, or material (all $p > 0.05$; see Figure 2) but did differ in the total number of descriptive statements (absolute number) they made during the interview. ITs made more descriptive statements than PTs ($t_{16} = 3.38$, $p = 0.004$, d = 1.59; ITs: M = 28.67, SD = 8.12; PTs: M = 17.67, SD = 5.41).

The cross-tabulations (see Supplementary Tables 1–3) performed on the verbal data show that the ITs described more aspects of the classroom, in more detail, than the PTs. For example, in the code "student," only the ITs mentioned specific learning-relevant aspects of the teaching, such as fidgeting students or learners having not yet started the assignment. The PTs' statements were more general and mainly concerned with the surface structure of the lessons, indicating, for example, that the students are working with tablets or are quiet. Moreover, the ITs made statements about alternative actions or possible thoughts and intentions of the observed teacher, but the PTs did not. Overall, ITs provided significantly more explanations than PTs ($t_{16} = 4.40$, $p < 0.001$, d = 2.07; ITs: M = 4.78, SD = 1.64; PTs: M = 2.11, SD = 0.78).

Comparison of video perspectives (RQ2)

Given that the teacher is barely visible in the eye-tracking perspective (only her arms and hands), the participants fixated on the teacher significantly less often (lower relative number of fixations) in this perspective than in the other two perspectives ($H_2 = 11.51$, $p = 0.003$, d = 2.68; eye-tracking: M = 1.5%, SD = 0.8%; front camera: M = 20.03%, SD = 8.6%; back camera: M = 21.5%, SD = 7.3%). Moreover, they fixated more often (higher relative number of fixations) on the material when viewing the

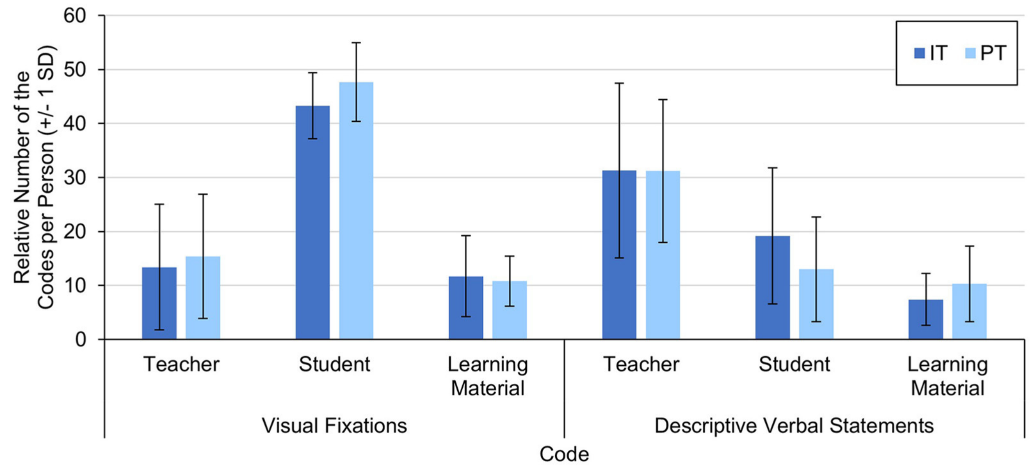

FIGURE 2
Comparison of ITs and PTs regarding the focus of their visual fixations and verbal statements.

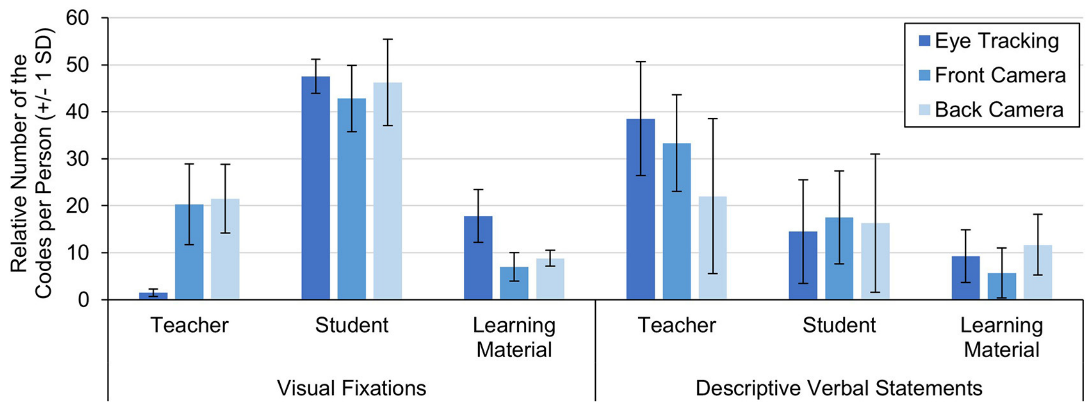

FIGURE 3
Comparison of the video perspectives regarding the focus of the visual fixations and verbal statements.

eye-tracking video than the videos from the observer's perspective ($F_{2,15} = 14.03$, $p < 0.001$, $d = 2.73$; eye-tracking: $M = 17.8\%$, $SD = 5.6\%$; front camera: $M = 7.0\%$, $SD = 3.0\%$; back camera: $M = 8.8\%$, $SD = 1.7\%$). No statistically significant differences between the perspectives occurred with respect to the relative number of fixations on the students ($p > 0.05$). No differences were found in the verbal data in the category "description," which had about the same relative number of codings per code for all three video perspectives (all $p > 0.05$) (see Figure 3).

Looking at the code "student" in the verbal data, remarkable differences between the perspectives become evident (see Supplementary Tables 4, 5). Participants who had viewed the video of the front camera and eye-tracking perspective reported that the students looked at the tablets, instead of listening to the teacher, while participants who had viewed the clip of the back camera perspective emphasized that the learners listened attentively to the teacher. Accordingly, the same teaching situation was perceived differently by the participants when viewing this video perspective.

Comparison of visual and verbal data (RQ3)

Overall, the participants fixated more often (higher relative number of fixations) on the students than on the teacher or material when viewing the video clips ($\chi^2_2 = 27.07$, $p < 0.001$, $W_{Kendall} = 0.75$; students: $M = 45.5\%$, $SD = 6.9\%$; teacher: $M = 14.4\%$, $SD = 11.2\%$; material: $M = 11.2\%$, $SD = 6.0\%$). In the interviews, however, they described more often (higher relative number) the teacher and her actions than the students or learning material ($F_{2,34} = 16.77$, $p < 0.001$, $d = 2.00$; teacher: $M = 31.3\%$, $SD = 14.3\%$; student: $M = 16.1\%$, $SD = 11.4\%$; learning material: $M = 8.9\%$, $SD = 6.0\%$) (see Figure 4).

To find an explanation for this discrepancy, the verbal data were reviewed more closely. It emerged that the participants often commented on the seating arrangement and number of students. As these are not actions of the students, such statements were not assigned to the "student" code but to the "no focus" code. It can be assumed that the participants often fixated on the students to gather information about the arrangement of the students and

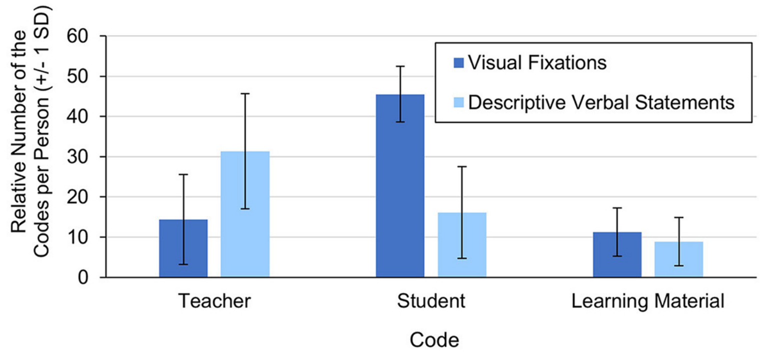

FIGURE 4
Comparison of visual and verbal data for the three codes teacher, student, and learning material.

the classroom. They seemed to pay less attention to the actions of individual students, which they described rather sweepingly; indeed, the students seem to have been perceived predominantly as a collective crowd. In contrast, the teachers' actions were usually the focus of attention and described in detail.

Discussion

This exploratory study uses a mixed-methods approach to examine the professional vision of PTs and ITs and investigates whether these groups differ in what aspects of a classroom they observe and describe (RQ1), whether the perspective of the video they viewed influenced their observations and descriptions (RQ2), and to what extent gaze behavior and verbal reports differ (RQ3).

Regarding RQ1, the results show differences in the professional vision of PTs and ITs. However, the differences could only be found in the verbal statements, but not in the visual data, in contrast with the findings of studies that identified differences in gaze behavior (e.g., Wolff et al., 2016; Kosel et al., 2021; Stahnke and Blömeke, 2021). Possible explanations for this difference could be that the participants in our study were not given a specific task while watching the video and there were no critical incidents in the classroom, as occurred in the aforementioned studies. Inconsistent results, however, have also been found in previous studies (e.g., Pouta et al., 2021; Seidel et al., 2021; van Driel et al., 2021). The differences in study results may be explained by the different task settings, as gaze patterns can be highly influenced by the specific task (Kaakinen, 2021). To identify differences in competence between novice and experienced teachers, the situation to be observed should be sufficiently complex as only then top-down processes typical of expertise will become relevant (Biermann et al., 2023).

As shown in other studies (e.g., Wolff et al., 2016; Meschede et al., 2017; Gegenfurtner et al., 2020), differences between the verbal statements of ITs and PTs were found. ITs overall made more statements in the interviews, describing more aspects of the classroom and giving more detailed descriptions and more explanations than the PTs. Moreover, only ITs mentioned possible thoughts and intentions of the observed teacher. These results indicate that ITs can grasp situations relevant to learning and better relate them to their job-specific knowledge (Gegenfurtner et al., 2020).

With respect to RQ2, we found differences between the three video perspectives. When viewing the eye-tracking video, participants fixated less often on the teacher than when viewing the other two perspectives as the teacher is barely visible in the eye-tracking video; instead, participants fixated more often on the learning material when viewing the eye-tracking video. They fixated on the students at the same frequency in all video perspectives. The findings indicate that, depending on the video perspective, different objects and individuals are brought into the viewer's focus.

The verbal data reveal no difference among the three perspectives regarding the number of codings per category. Although participants fixated significantly less frequently on the teacher when viewing the eye-tracking video than the videos from the observer's perspective, when interviewed they still talked at the same frequency about the teacher as for the other perspectives. This result is inconsistent with the findings of Cortina et al. (2018); however, in their study, the participants worked with their own eye-tracking videos, whereas the participants in the present study viewed video clips of other teachers. Nevertheless, the findings are remarkable. They indicate that the participants strongly consider teaching from the teacher's perspective (Sherin and Han, 2004), regardless of the camera perspective. As other scholars have observed (Blomberg et al., 2014), our results confirm that work with classroom videos should be guided and accompanied by appropriate prompts to increase the focus on student learning. The results also raise the question of how "noticing" and "knowledge-based reasoning" are related. It would thus be highly appreciated if future research studies were to focus more on this question.

Concerning RQ3, the results show that gaze behavior and verbal reports are not necessarily consistent. The participants fixated more often on the students than the teacher or the material when viewing the video clips. When interviewed, however, they talked more often about the teacher than the students or the learning material. This finding indicates that it is not always possible to draw clear conclusions about the focus of attention from gaze behavior. An important difference between eye-tracking data and verbal data is that eye-tracking captures both conscious and unconscious processes, while verbal data are limited to conscious, verbalizable processes (Godfroid et al., 2020). Visual data alone are therefore insufficient to draw conclusions about professional vision, but teacher's gaze can provide very valuable additional information (Minarikova et al., 2021).

In interpreting the results, some limitations must be considered. Due to technical problems with the eye-tracking recordings, the final number of participants was small. Although eye-tracking technology has continuously improved, there are still certain technical hurdles. Careful monitoring of data collection is thus advisable. Moreover, the participants worked with clips from a single teaching lesson. Consequently, the study must be characterized as an exploratory study. It is necessary to explore the results further with larger samples and more and different classroom clips. As the small number of participants was unforeseen, we will expand the study with additional participants. Nevertheless, the study revealed some valuable findings that provide a basis for future research as well as teacher education. When working on professional vision, the video perspective to be used should be taken into account, and it also seems useful to consciously choose a particular perspective, considering the advantages and disadvantages of each perspective in the context of fostering professional vision. An important finding is that as gaze behavior and verbal reports give different indications of and insights into a person's professional vision, combining these types of data is valuable. Moreover, the use of qualitative and quantitative methods is advantageous. Combining these different data provides a promising way to explore the relationship between "noticing" and "knowledge-based reasoning" as well as to better support novice and experienced teachers in developing their professional vision competencies.

Data availability statement

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

Author contributions

CW: Conceptualization, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. KB: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. SM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Project administration, Visualization, Writing – original draft, 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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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1282992/full#supplementary-material

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Individual learning paths mastering teachers' professional vision

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Introduction: Promoting a professional vision of teaching as a key factor of teachers' expertise is a core challenge for teacher professionalization. While research on teaching has evolved and successfully evaluated various video-based intervention programs, a prevailing emphasis on outcome measures can yet be observed. However, the learning processes by which teachers acquire professional vision currently remain a black box. The current study sought to fill this research gap. As part of a course dedicated to promoting a professional vision of classroom management, students were imparted knowledge about classroom management that had to be applied to the analysis of authentic classroom videos. The study aimed to determine the variety of individual strategies that students applied during their video analyses, and to investigate the relationship between these and the quality of the students' analyses, measured by their agreement with an experts' rating of the video clips.

Methods: The sample comprised 45 undergraduate pre-service teachers enrolled in a course to acquire a professional vision of classroom management. By applying their imparted knowledge of classroom management, students engaged in the analysis of classroom videos to learn how to notice and interpret observable events that are relevant to effective classroom management. Implementing a learning analytical approach allowed for the gathering of process-related data to analyze the behavioral patterns of students within a digital learning environment. Video-based strategies were identified by conducting cluster analyses and related to the quality of the students' analysis outcomes, measured by their concordance with the experts' ratings.

Results: We gained insight into the learning processes involved in video-based assignments designed to foster a professional vision of classroom management, such as the areas of interest that attracted students' heightened attention. We could also distinguish different approaches taken by students in analyzing classroom videos. Relatedly, we found clusters indicating meticulous and less meticulous approaches to analyzing classroom videos and could identify significant correlations between process and outcome variables.

Discussion: The findings of this study have implications for the design and implementation of video-based assignments for promoting professional vision, and may serve as a starting point for implementing process-based diagnostics and providing adaptive learning support.

KEYWORDS

professional vision of classroom management, noticing, knowledge-based reasoning, video-based learning, learning analytics, learning path, pre-service teacher training, analysis strategies

1 Introduction

Professional vision is a key aspect of teachers' expertise (Seidel and Stürmer, 2014; Stürmer et al., 2014). Consequently, the effective promotion of a professional vision is a core theme and challenge of teachers' professionalization.

Over the past two decades, many interventions have been conducted that have identified successful methods for promoting a professional vision of pre-service teachers. However, most of these interventions focused on the question of what supports the outcomes best, whether it was the medium of content (video vs. written vignette), personal engagement (own vs. other teachers' video), or the kind of feedback on students' results from analysis (e.g. feedback from experts vs. peers) (Sherin and van Es, 2009; Baier et al., 2021; Prilop et al., 2021). Studies to date have not yet focused primarily on the ongoing process of analyzing classroom videos (König et al., 2022; Gold et al., 2023), for example, the type and choice of strategy participants applied, or, in short, professional vision in the making.

One process-oriented method is the study of the eye-tracking gaze data of participants while they are watching a real or videotaped lesson. Eye-tracking focuses on spatial perception by analyzing eye movements and fixation, which has already yielded numerous valuable results (Gegenfurtner and Stahnke, 2023). A promising alternative approach to consider is the use of Learning Analytics (LA), which can be adapted but still has to establish its suitability for a process-oriented analysis of professional vision, particularly in line with learning designs (Ahmad et al., 2022). This method facilitates the exploration of data from digital educational learning environments to make learning measurable and visible by using and extending educational data mining methods to gain insight into learning, unveiling the black box that learning processes still pose (Long et al., 2011; Siemens and Baker, 2012; Siemens, 2013; Roll and Winne, 2015; Hoppe, 2017; Knight and Buckingham Shum, 2017). In the present study, Learning Analytics was utilized to identify video-based strategies and potential barriers to learning in relation to pre-service teachers' analyses of authentic classroom videos, primarily focused on the professional vision of events relevant to effective classroom management.

This study introduces novel perspectives on identifying successful and less successful strategies for analyzing classroom videos within the field of teachers' professional vision. In addition, it showcases an approach to process-based learning diagnostics for acquiring a professional vision of classroom management. Developing the ability to perceive, interpret, and respond effectively to complex classroom situations is essential to preparing pre-service teachers for their future profession. This expertise plays a pivotal role in fostering a conducive learning environment for improving learning engagement and outcomes. Proactive classroom management empowers teachers to anticipate and prevent potential learning disruptions while maintaining a productive learning environment. Understanding cues relevant to learning enables teachers to intervene, adapt, and tailor their teaching to the individual needs of students or situations, enhancing the overall effectiveness of their lessons.

1.1 Teachers' professional vision

Professional vision is a prevalent construct in German teacher education, derived and adapted from the American researchers Goodwin (1994) and Sherin (2001). According to the Perception-Interpretation-Decision-model of teacher expertise (PID-model), professional vision can considered an important situation-specific skill for teaching, mediating between cognitive and motivational dispositions and performance (Sherin and van Es, 2009; Blömeke et al., 2015; Kaiser et al., 2015). Professional vision is commonly defined as a teacher's skill in noticing and interpreting significant classroom events and interactions that are relevant to student learning (van Es and Sherin, 2002; Sherin, 2007; Sherin and van Es, 2009; König et al., 2022), and making situationally appropriate decisions on how to proceed during a lesson (Blömeke et al., 2015; van Es and Sherin, 2021; Gippert et al., 2022). While noticing requires selective attention to perceive significant cues for learning and to neglect insignificant ones, interpreting depends on the application of appropriate knowledge in a subsequent process, often referred to as knowledge-based reasoning (Sherin and van Es, 2009; Blomberg et al., 2011; König et al., 2014; Seidel and Stürmer, 2014; Gaudin and Chaliès, 2015; Barth, 2017). The extent of mastering these skills indicates the quality of situated knowledge (Kersting et al., 2012; König et al., 2014; Seidel and Stürmer, 2014). Studies have revealed that the quality of professional vision is positively related to instructional quality, to teaching effectiveness in general (Sherin and van Es, 2009; Yeh and Santagata, 2015), as well as to the learning outcomes of students (Roth et al., 2011; Kersting et al., 2012; König et al., 2021; Blömeke et al., 2022), however, some ambiguous results regarding the association between professional vision and teaching performance have emerged in the past (Gold et al., 2021; Junker et al., 2021), additionally implying the challenges involved in measuring this construct.

1.2 Video-based promotion of professional vision using annotation tools

Linking theoretical knowledge with teaching situations poses a challenge for students, given the inconsistent availability of practical experience during their university studies. The analysis of recorded lessons to promote professional vision in teacher training constitutes an opportunity to address that challenge. Video-based training can nowadays be considered an effective and well-established practice to promote professional vision with a knowledge-based focus (Sherin and van Es, 2009; Santagata and Angelici, 2010; Santagata and Guarino, 2011; Gaudin and Chaliès, 2015; Weber et al., 2018; Gold et al., 2020; Santagata et al., 2021). This kind of video-based setting enables acquiring case-based knowledge, using authentic examples to bridge the gap between theory and practice by reviewing prototypical interactions (Zumbach et al., 2007), such as those from authentic classroom videos. It has also been shown that video-based learning environments help learners produce more sophisticated and in-depth analyses (van Es and Sherin, 2002; Star and Strickland, 2008; Stockero, 2008; Santagata and Guarino, 2011; Barnhart and van Es, 2015; Gold et al., 2020). Therefore, classroom videos are considered an appropriate medium for the application of situated concepts, taught to link knowledge and performance (Seidel and Stürmer, 2014; Barth, 2017).

These objectives can be facilitated by learning environments that provide features for coping with the complexity of teaching and the volatility of interactions in a classroom, such as the ability to pause and repeat certain sections of the video, allowing the breakdown of classroom interactions into smaller segments for a more in-depth analysis. These types of interactive features have been shown to endorse learning processes in other educational settings (Schwan and Riempp, 2004; Blau and Shamir-Inbal, 2021). Annotation tools incorporate these features and support reflective practices by enabling users to annotate video content in a structured manner. They can be used to segment a video, preserve and synchronize enhanced observations with the video timeline (Rich and Trip, 2011; Kleftodimos and Evangelidis, 2016), and are also suitable for a wide range of educational and research applications (Catherine et al., 2021). Annotation tools have previously been used effectively to develop, reflect, and evaluate students' pre-service teaching practices and those of a learning peer group (Rich and Hannafin, 2008; Colasante, 2011; McFadden et al., 2014; van der Westhuizen and Golightly, 2015; Ardley and Johnson, 2019; Nilsson and Karlsson, 2019; Ardley and Hallare, 2020), besides to analyzing classroom videos of third-party teachers (Hörter et al., 2020; Junker et al., 2020, 2022c; Larison et al., 2022). Interactive annotation tools can foster professional vision by engaging students in sophisticated analysis for a profound understanding of classroom interactions at their pace (Schwan and Riempp, 2004; Risko et al., 2013; Merkt and Schwan, 2014; Koschel, 2021).

1.3 Professional vision of classroom management

Applying Learning Analytics to reveal strategies for analyzing classroom videos requires an analytical focus on the dimensions of teaching in classrooms that should be noticed and interpreted. Classroom management represents one of the pivotal dimensions of teaching quality, alongside cognitive activation and support for student learning (Praetorius et al., 2018; Junker et al., 2021). It involves different facets and denotes instructional strategies aimed at fostering an environment conducive to effective learning (Emmer and Stough, 2001). This includes the deliberate orchestration of teaching, encompassing the establishment of rules and routines, seamless structuring, monitoring, and pacing of classroom activities, along with the prevention and prompt resolution of any learning disruptions or misbehavior that may interfere with the learning process (Kounin, 1970; Wolff et al., 2015; Gold and Holodynski, 2017). To ensure a continuous learning process, it is essential to organize the pacing of activities and manage transitions smoothly (Kounin, 1970). Likewise, established rules provide comprehensible scopes of action, structuring interactions, and contributing to a positive relationship in the classroom (Kounin, 1970). By anticipating and perceiving learning disruptions, teachers can take proactive and reactive actions to either prevent their occurrence or remediate them early on (Kounin, 1970; Emmer and Stough, 2001; Simonsen et al., 2008). Moreover, responding adaptively to classroom situations and individual student needs contributes to maintaining a productive and supportive environment while maximizing effective learning time. This kind of pedagogical knowledge is positively associated with the learning interests and outcomes of students (Kunter et al., 2007, 2013; Seidel and Shavelson, 2007; Evertson and Emmer, 2013; Hattie, 2023). Thus, managing classrooms professionally is an important dimension of teaching quality (Shulman, 1987; König, 2015; Hattie, 2023).

Professional vision of classroom management includes the situated application of this knowledge and can be considered a prerequisite for managing classrooms successfully and effectively. Because professional vision is associated with such essential skills, it is reasonable to assume that the acquisition of professional vision is necessary for teacher education (Blömeke et al., 2015, 2016). The complexity of teaching arises, among other factors, from the simultaneous occurrence of various events in the classroom (Doyle, 1977; Jones, 1996; Wolff et al., 2017), placing high demands on the management of heterogeneous learning groups. To address these demands, video-based courses aim to promote students' ability to notice and interpret classroom events as a basic requirement for their professional decision-making in the future. Because professional vision can be considered a domain-specific skill based on acquired knowledge (van Es and Sherin, 2002; Steffensky et al., 2015), classroom management serves as a foil for noticing, interpreting, and decision-making related to observable classroom events.

1.4 Video-based analysis strategies revealed by Learning Analytics

Learning Analytics collects, aggregates, analyzes, and evaluates data from educational learning contexts to make learning measurable and visible, opening the black box that learning processes have posed to date. It extends educational data mining methods to gain insights into learning, to tailor content to the learners' needs, to predict and improve their performance, and to identify success factors and potential barriers concerning learning activities and student behavior (Long et al., 2011; Chatti et al., 2012; Siemens and Baker, 2012; Siemens, 2013; Hoppe, 2017; Knight and Buckingham Shum, 2017).

Learning Analytics can be deployed in educational contexts to better understand video-based learning. This media-specific type of analytics focuses on learner interactions with the video content and the context in which they are embedded (Mirriahi and Vigentini, 2017). Combining and triangulating this data pool with survey and performance data can provide an even more sophisticated view (Mirriahi and Vigentini, 2017). A main interest of this research is to explore the practical application of Learning Analytics when analyzing authentic classroom videos.

1.4.1 Video usage analytics based on clickstreams

Video usage analytics can rely on explicit factors, such as the number of views and their impact on learning outcomes, and implicit factors, such as events emitted by digital learning environments (Atapattu and Falkner, 2018). Córcoles et al. (2021) conclude that this type of data can be valuable for instructors to enhance the learning process, even in limited-scale applications such as ours. Gašević et al. (2016) and Ahmad et al. (2022) suggest that conducted analytics must be adapted to the course context and its learning design. In our study, we use both types of factors to identify participants' analysis strategies and evaluate their concordance with learning outcomes. Video-based analysis strategies can be depicted as patterns of interactions that learners exhibit in a digital learning environment (Khalil et al., 2023). Within educational contexts, these kinds of patterns are commonly referred to as clickstreams, which can be composed and gathered in different ways. Clickstreams are digital representations of learning processes that encapsulate the behavior and interactions of learners as they engage in a digital learning environment. Clickstream data typically comprises a sequence of interactions performed by learners and environmental events that occurred within the learning process. This data stream refers to a sequence of actions that are captured within the learning activity, usually representing an individual learning journey. Logged data may include more than interactions within digital learning environments. Beyond that, several indicators could be derived from clickstreams, such as emitted events or the context and time spent on parts of the learning activity. By incorporating contextual data, the clickstream can be expanded. Depending on the implementation, clickstreams reveal individual learning paths across all logged activities, allowing longitudinal studies and cross-activity comparisons, for example, throughout a semester. Previous studies have collected clickstream data to analyze behavioral patterns and students' engagement with learning activities. These studies serve as an orientation for extracting promising measures that can be applied to the analysis of classroom videos, and for providing ideas regarding the feasibility and expectancies of such an application. To derive our hypothesis, substantiate methods as well as data pipelines for our use case, and provide references to promising measures for conceptualizing video-based analysis strategies, previously conducted research was considered and is outlined in the following section.

1.4.2 Conceptualizing, evaluating, and categorizing student approaches to video-based learning

To investigate and explain students' video-viewing behavior, events that occur in the learning environment, such as *play*, *pause*, and *seek* interactions from the video player, can be collected and evaluated (Giannakos et al., 2015; Atapattu and Falkner, 2018; Angrave et al., 2020; Hu et al., 2020). A more profound investigation of video engagement is enabled by features of video-based learning, including when and how often videos are (re-)viewed (Baker et al., 2021; Zhang et al., 2022), or which and in what order video segments are played, repeated, and viewed more frequently (Brinton et al., 2016; Angrave et al., 2020; Khalil et al., 2023). This facilitates the reconstruction of students' video-viewing sequences and provides insights into the context and time devoted to segments of the footage. Video interaction behavior analysis has proven to be informative, particularly when exploring the relationship between student engagement and learning success (Delen et al., 2014; Atapattu and Falkner, 2018). It supplies researchers with evidence that engagement patterns might predict performance. Clickstream data approaches, which are used to investigate this kind of relationship, show that engagement patterns affect student learning performance, and that there is a coherence between the viewing behavior and the students' performance (Giannakos et al., 2015; Brinton et al., 2016; Lan et al., 2017; Angrave et al., 2020; Lang et al., 2020). Indeed, Clickstream data possesses the potential to serve as a predictive model of learners' performance (Mubarak et al., 2021) and to characterize learners and their likelihood of achieving success in a course.

Therefore, identifying students who are on-track, at-risk, or off-track is an important aim of categorizing learners in educational contexts (Kizilcec et al., 2013; Sinha et al., 2014). This categorization enables targeted interventions and the development of adaptive features. To cluster learners based on their activity patterns and how they achieve their learning goals, Brooks et al. (2011) created an event model for user interactions with a video player, concluding that there are different types of learners concerning time management. Similarly, Kizilcec et al. (2013) classified learners according to patterns of engagement and disengagement with lecture videos, while Sinha et al. (2014) examined the learning effectiveness by delving into clickstream data containing interactions with a video player. To analyze the clickstream data, they grouped behavioral actions into higher-level categories that served as a latent variable, for example, re-watching. Through the characterization of student engagement based on patterns of interactions, learners could be classified into groups that display either low or high engagement. Mirriahi et al. (2016) and Mirriahi et al. (2018) conducted studies to explore student engagement with an annotation tool, thereby providing a comparable environmental setting to our study case. The purpose of this tool was to facilitate reflection on practice and encourage self-regulated learning. During the annotation process, further contextual metadata was captured, such as timestamps for creating, editing, and deleting annotations. They found clusters that characterized different learning profiles, separated by the extent and point in time of their engagement. Khalil et al. (2023) tracked video-related behaviors (like playing, pausing, and seeking) and further video-interaction metrics (e.g. duration of session, maximum progress within the video) across different contexts by video analytics to reveal patterns and cluster video sessions based on the segments watched on the timeline. A common trait among these studies is their utilization of clustering approaches to uncover patterns, despite indicator variations between environments.

To further investigate any presumable associations between interactional patterns and learners' performance, Li et al. (2015) categorized video sessions according to the characteristics of interactions in terms of frequency and time. To achieve clustering, several features were extracted, such as the number of pauses and seeks. The results showed significant differences between behavioral patterns and the resulting performance. In a similar manner, Yoon et al. (2021) delved into the analysis of behavioral patterns and learner clusters within video-based learning environments, showing that learners who actively engaged exhibited greater learning achievement.

Overall, the studies indicate that gathered clickstream data can be used to discriminate and categorize different approaches to video-based learning. Various behavioral analyses led to the classification of learners in terms of their engagement with the videos. Studies have also identified relationships between engagement behavior and performance using explicit factors, like views or annotations (Barba et al., 2016), and implicit factors, such as types of interaction, like *playing*, *pausing*, or *seeking* within a video (Atapattu and Falkner, 2018). Most studies mentioned focus on large-scale samples, such as Massive Open Online Courses (MOOC). Although studies analyzing exhibited strategies in digital video-based learning environments can be identified in other contexts, there are currently none in the field of professional vision, to the best of our knowledge. However, it can be assumed that similarities in learning formats allow at least some application of the approaches to this domain-specific context. It should be noted that most studies look at interactional behavior during video-viewing, but not at the process of analyzing videos. It is to be expected that interaction patterns in video-based analysis tasks will differ from patterns in video-viewing. Also, other studies typically examine videos that can be seen as an alternative format for conveying content, such as lecture recordings, implying that the videos do not represent the content but rather serve as a medium for presenting it. In our study, the videos act as the content that participants must engage with. As a result, the ways in which individuals engage with lecture recordings are likely distinct from those when analyzing authentic classroom videos, requiring consideration of the video type, activity, and environment. Different ways of conceptualizing and measuring engagement (e.g. Chi and Wylie, 2014; Angrave et al., 2020; Yoon et al., 2021) need to be contemplated, with an awareness of the learning context and goals (Trowler, 2010).

1.5 Aim of this study

Pre-service teachers struggle to identify relevant events in classroom videos selectively (van den Bogert et al., 2014) due to their lack of knowledge and experience (Sherin and van Es, 2005; Blomberg et al., 2011; Stürmer et al., 2014) and their tendency to "focus on superficial matters [. . .] and global judgments of lesson effectiveness" (Castro et al., 2005, p. 11). In contrast, in-service teachers reveal more astute perceptions of classroom events that are relevant for learning (Berliner, 2001; Stahnke et al., 2016), thus disclosing differences between novices and experts in terms of what and how they perceive classroom events (Carter et al., 1988; König and Kramer, 2016; Meschede et al., 2017; Wolff et al., 2017; Gegenfurtner et al., 2020). Using eye-tracking and gaze data, differences in eye movements and fixations were found between novices and experts (Seidel et al., 2021; Huang et al., 2023; Kosel et al., 2023), uncovering disparate patterns of noticing concerning their professional vision. This leads to the assumption that video-based analysis strategies also differ regarding the state of expertise. Furthermore, questions arise as to what extent video-based analysis strategies of pre-service teachers vary among each other and which relationships can be identified between individual learning paths and the respective learning outcomes, primarily concerning selective attention and knowledge-based reasoning as skills related to professional vision.

While the positive outcomes of video-based learning activities developing professional vision have already been confirmed empirically, we do not know how students engage in analyzing classroom videos, which different strategies can be identified, and how they are related to appropriate noticing and interpreting of classroom management practices in the analyzed videos. It is evident that not all students apply learning activities in a way that effectively supports their learning process (Lust et al., 2011, 2013), but what distinguishes successful from less successful strategies?

One aim of this study is to identify and discriminate successful from less successful strategies that were used to cope with the video-based assignments set in the context of a university course on promoting a professional vision of classroom management. To achieve this, the present study uses a novel approach in the domain of professional vision by combining a learning analytical approach and educational data mining methods. This introduces new possibilities for gaining insights into specific learning processes in the context of acquiring professional vision by capturing and evaluating video-based strategies in a digital environment, such as a video annotation tool that accompanies the learning activities of pre-service teachers.

The following two research questions and hypotheses reveal the starting point of our explorative study. We expect findings that reflect the discussed research regarding the difference in noticing patterns and related findings, similar to research approaches in other domains and contexts.

Q1: What are the characteristics of and differences between students' video analysis strategies?

- H1.1: Video analysis strategies can be derived and discriminated using Learning Analytics
- H1.2: Students exhibit meticulous and less meticulous video analysis strategies

Q2: What distinguishes successful from less successful video analysis strategies?

- H2.1: Video-based analysis strategies relate to learning outcomes
- H2.2: The more meticulous the video-based analysis, the better the outcome, measured as the agreement between students' and experts' ratings of the analyzed classroom videos.

This study investigates the behavioral patterns of students' engagement with an annotation tool while analyzing authentic classroom videos, as well as features of students and their learning processes in relation to the outcome of their respective learning.

2 Materials and methods

2.1 Sample

Participants enrolled in the elective university course according to their curriculum. The participants in this study consisted of 45 undergraduates enrolled in a teacher training program for elementary school. These students were pursuing a bachelor's degree at the University of Münster in Germany (North Rhine-Westphalia). Overall, 38 students stated that they are female, and 5 students stated that they are male. The distribution of gender is quite typical, given the study objective of prospective elementary school teachers. On average, the students were 21 years old, and 91% of them were in the fourth semester of their six-semester total (standard) study period (see **Table 1**).

2.2 Session structure for acquiring professional vision

To acquire a professional vision through video-based analyses of lesson clips, a blended learning environment is provided to students, integrating various modes of learning. In comparison with traditional modes of instruction, there is evidence that blended learning approaches tend to more effectively promote student engagement and performance (Chen et al., 2010; Al-Qahtani and Higgins, 2013). The session structure is based on a prototype for video-based teaching in the context of professional vision proposed by Junker et al. (2020), which takes media-didactic principles into account, such as the cognitive theory of multimedia learning (Mayer, 2014) as well as the cognitive apprenticeship theory (Collins et al., 1989), as the lecturer demonstrated the analysis as an expert model, scaffolded with feedback, and also supported articulation and reflection in plenary discussions.

TABLE 1 Course demographics.

Demographics	Range	Minimum	Maximum	Mean	SD
Age	19	19	38	21.38	3.052
Semester	4	2	6	4.10	0.617

The structure comprises different sessions that build upon each other, increasing the demands with the progression of learning. The content of the course is divided into several sessions, including an introductory session that familiarizes learners with the basic concepts and learning objectives of the course, serving as an advance organizer. Thereupon, new facets of classroom management are introduced weekly, starting with the facet "Rules, Routines and Rituals," followed by "Monitoring" and "Managing momentum" (Gold and Holodynski, 2017; Gold et al., 2020). Overall, the learning material is presented in a learning management system (LMS) based on the open source software Moodle (RRID:SCR_024209). This approach promotes self-regulated learning and enables students to access and revisit material as needed. Included activities can be carried out at the student's own pace.

Phases of collaborative, synchronous blended learning take place at the university. These sessions consist of a theoretical introduction to a facet of classroom management and guided exercises using a video annotation tool to practice noticing and interpreting relevant classroom events related to the specific facet in focus. The aim is to introduce new concepts to students in a guided manner, so as to ensure comprehension. Participants are provided the opportunity to practice through exercises within a video-based annotation tool during the session and discuss the results of their work in plenary.

In contrast to exercises within the sessions, asynchronous phases provide a self-regulated analysis assignment of an authentic classroom video. In order to prepare for these assignments, participants had to complete an interactive quiz that helped them recollect and reinforce the learning contents covered in the presence phase, thereby aligning their knowledge baseline. This prerequisite provides instant feedback to students regarding their theoretical knowledge of the current session phase. A working time of 60 min is proposed to establish a consistent reference point for the assignments. No time limit is enforced during the activity, nor are students given direct feedback on the actual time spent, thus promoting self-regulation skills simultaneously with the learning activity. These asynchronous phases facilitate a more in-depth understanding of concepts through their application in video-based assignments, and allow students to self-assess the skills they have acquired through completing the assignments and reflecting on them independently. In addition, instructors can use the results to identify common misconceptions and to tailor subsequent instruction and guidance to the needs of the group. This advantage of a blended learning pattern creates a more personalized learning experience for the course.

2.3 Instruments

2.3.1 Classroom videos

For the video analyses, three video clips were selected, and the video-based assignments were carried out in the listed order (see **Table 2**), each with a 2-week time offset. The videos and clips used in this course originate from the portals "ViU: Early Science" (Zucker et al., 2022) and "ProVision" (Junker et al., 2022b). Seamless access to the portals for the pre-service teachers was established through the Meta-Videoportal unterrichtsvideos.net (Junker et al., 2022a).

TABLE 2 Description of the selected classroom videos.

Metadata	Clip 1 (be45e9e16c)	Clip 2 (d24a5798c0)	Clip 3 (59f08d6bc0)
Duration	203 seconds	215 seconds + context	175 seconds + context
Grade	2	3	5
Subject	Early science	Early science	Geography
Topic	Floating and sinking	Aggregate states	Agriculture
Content	The clip shows the teacher's presence during a station work phase in which students check their assumptions about whether objects float or sink (ViU: Early Science, 2023b).	In the observed clip, students reflect on the extent to which the rules were followed in the previous work phase (ViU: Early Science, 2023a).	The clip shows the teachers' support in a working phase of students about modern agriculture practices (ProVision, 2023).

Prior to analyzing the selected video clip, contextual information about each lesson was given to help students understand the goal and content. Clip 1 showed an excerpt from a lesson, whereas clips 2 and 3 were embedded in the context of an entire lesson. In terms of the assignment, this means that the students were able to view more contextual video content in clip 2 and clip 3, beyond the temporal boundaries set by the assignments. Upon launching the annotation tool, the starting frame was automatically set to the defined time for the respective analysis. Consequently, in the subsequent subsection, we refer to video progress based on the provided analysis periods, with 100% progress indicating complete viewing of the specified section. Progress values exceeding 100% show that students have accessed additional teaching context outside the provided time intervals.

2.3.2 Coding manual for observable events related to classroom management

Participants were introduced to a coding manual of observable classroom events which are structured along the three facets of classroom management, namely “Monitoring,” “Structuring momentum,” “Rules, Routines and Rituals,” and their sub-facets according to a coding manual of Gippert et al. (2019). The manual contains labeled codes and explanations for each facet and sub-facet. This serves as a framework for supporting the analysis of classroom videos, directing students' attention to specific aspects of the video. It standardizes observations and vocabulary use by providing meaningful codes for relevant classroom events. The provided coding manual is used to analyze authentic classroom videos by annotating segments of the video with specific codes whenever an event significant to classroom management occurs that corresponds to the sub-facets. The list of sub-facets limits the relevant events that need to be observed by basic cueing principles and therefore reduces the cognitive load during activities (Guo et al., 2014; Mayer and Fiorella, 2014; van Gog, 2014).

2.3.3 Video-based assignments

The video clips were analyzed using the open source, web-based Opencast Annotation Tool (OAT; RRID:SCR_023934). This digital video annotation tool is part of a local on-premises video streaming and research service which is based on Opencast (RRID:SCR_024764). The OAT is initialized by the students through the LMS, using the learning tools interoperability (LTI) e-learning standard, to achieve a seamless learning experience. By supplying the annotation tool with individual access roles, a pseudonymous identifier, and the course context, students can utilize their existing single sign-on session (SSO) for authentication and authorization, which is pertinent because of legal restrictions on viewing authentic classroom videos. To ensure the protection of privacy for individuals who have consented to the collection of learning data, as well as the teachers and students featured in the classroom video, it is essential to establish proper authorization measures. This type of implementation also creates a protected digital learning space that keeps learning activities and interactions within the established learning context. Ensuring a comfortable learning environment is vital for maintaining a focused learning process, allowing for interpretive and evaluative mistakes, and encouraging collaboration and discourse between students and instructors. The annotation tool serves as a digital learning environment and offers several features for analyzing videos (see Figure 1). The features of the annotation tool can help students observe volatile classroom events. In our study, the OAT was used to annotate classroom videos with the provided coding manual and a specific annotation template.

Categories and codes. The annotation tool assists the analysis tasks by providing a user interface to annotate the video with codes from color-coded categories representing the facets of classroom management required for analyzing the lesson recordings in our use case.

Views and playback controls. Students can navigate video reception with basic playback controls, such as play, pause, loop, and seek. Switching to full screen allows for focusing on details, including background interactions. The tool experience can be personalized with unique split-screen views by adjusting the feature areas.

Timeline, Tracks, Annotation types. Annotations are organized and viewed with precision using a timeline. The timeline aids in recognizing specific segments of the video along with the annotated content. Students can create connected multi-content annotations (MCA) using various annotation types, for example, by combining free text and codes with or without a scale. Annotations containing codes are displayed in a color-coded format and can be arranged on multiple tracks in the timeline.

2.4 Data collection

2.4.1 Capturing video-based analysis strategies revealed by Learning Analytics

To collect measures composing the strategies, we extended the OAT with the capability to exchange data that is compliant with the Experience Application Programming Interface (xAPI) e-learning standard, following the specifications of the Advanced Distributed

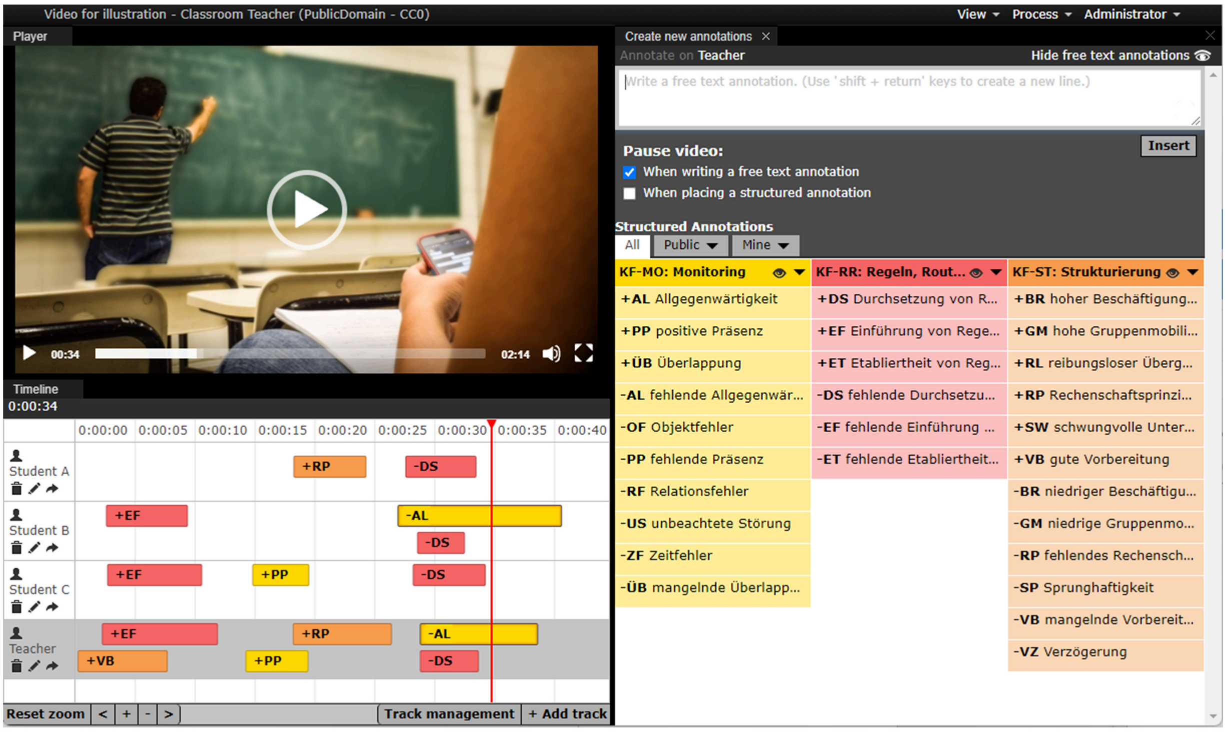


FIGURE 1
Video annotation tool used to analyze classroom videos.

Learning Initiative (ADL, 2017). This enables data gathering from learning experiences in a standardized format, such as video-based assignments, using the OAT. To store the generated data on our premises, we deployed a compliant Learning Record Store (LRS). This data repository stores the data issued by the OAT, which acts as a relaying Learning Record Provider (LRP). The data model itself and the web service conform to the IEEE 9274.1.1 standard (IEEE, 2023). An implementation of a player adapter serves as a proxy between the video player and other components within the OAT, managing events related to the player that occur during tool usage. This setup allows for a standardized retrieval of events within the video-based exercises and assignments.

The structure of the transmitted data is defined by xAPI, consisting primarily of statements issued by the LRP (ADL, 2019). Statements include (meta-)data about the learner (actor), the specific type of interaction (verb), the related video-based exercise or assignment (object), and contextual (context) or outcome-related information (result) (ADL, 2019; xAPI Video Community of Practice, 2019b). Statements are used for describing data points of events, indicating individual experiences in a learning activity, for example:

> A *student* (actor) can *pause* (verb) the video in the *learning activity* (object) within a specific *session* (context) and might have achieved outcomes, for example, a set of *segments played* (result) so far.

Because there can be various experiences within learning activities, a standardization of the statements beyond the structure is necessary. To enhance the semantic interoperability of the data, we adapted the official xAPI Video Profile v1.0, created by the ADL xAPI Video Community of Practice (2019b). This application profile standardizes statement content and prevents fragmentation across implementations. It defines a default set of rules regarding the use of statements and concepts, such as types of interactions based on a controlled vocabulary (verbs), to ensure that the interpretation and meaning of the data are consistent between platforms. Based on the previous explanations, the specific nature of the learning activity must be kept in mind. The profile is limited to video-based experiences. Since our learning activity is not a purely reception-oriented experience, it is necessary to extend this default set to better track the learning experiences and related interactions within the OAT. Therefore, we reused related concepts from the xAPI Profile Server (ADL, 2023) and the xAPI Registry (Brown, 2018), such as the standardized verbs *annotated*, *commented,* and *replied* as types of interaction that can also occur in the OAT, complementing the xAPI Video Profile. We were able to obtain several measures that are used to express the composition of video-based strategies and outcomes.

2.4.2 Measures of video-based analysis strategies

Measures expressing video-based strategies were extracted from the databases (see Table 3). The gathered xAPI statements included the following interactional events: *played*, *paused*, *completed*, *interacted (toggle full-screen video-viewing)*, *seeked* [*sic*] (xAPI Video Community of Practice, 2019a). The data was aggregated by the respective video activities and students. This enables tracing individual learning paths based on sequential viewing and interactional behavior as well as the annotation

TABLE 3 Process measures.

Measure	Description
Count of sessions	The number of sessions, based on launching and exiting the annotation tool.
Count of statements	Number of interactional events that occurred
Count of {event} statements	Number of a specific interactional event (*played*, *paused*, *seeked*, . . .)
Count of played segments	Number of video segments played (e.g. the time interval from 50 to 60)
Progress according to task (%)	Percentage of the video viewed according to the assignment
Effective watch-time	Minutes of video content that were watched effectively
Count of revisions	Number of revisions made to any annotation created (e.g. in terms of the arrangement in the timeline or at a content level)

process, including creating and revising annotations on the video timeline.

2.4.3 Outcome measures

Measures expressing learning outcomes were extracted as well (see **Table 4**). Learning outcomes that are related to the quality of the participants' professional vision of classroom management were assessed by comparing the participants' annotations of each video clip with the annotations of experts, resulting in an agreement score. A rating of experts ($n = 4$) was used to compare the quality of the analysis. To create this rating, experts were asked to use the coding manual to annotate relevant events in the respective video clips. The resulting experts' rating served as a reference for the evaluation of students' codings.

2.5 Data analysis

2.5.1 Cluster analyses of process-related measures

We conducted cluster analyses to identify structures, separating students based on distinguishable analysis strategies. According to our assumption, we expected to find at least two groups, classified into (1) meticulous analysts, who performed a fine-grained analysis with great diligence, and (2) students with a more superficial view of and engagement with the video content. Therefore, we expected at least two derivable clusters (meticulous and less meticulous analysts).

2.5.1.1 Cluster analysis I (played segment data)

Although we already expected a certain number of clusters, we did not split up the data into a pre-defined number of clusters but analyzed the data in a more explorative bottom-up manner within the data pool of our video clips. Hierarchical clustering enables us to gain this knowledge directly from the data, without relying on assumptions about the shape or size of clusters. Given the intention of merging students based on their approach to video-based analysis, the hierarchical clustering method is a suitable choice. The data was hierarchically clustered using normalized Euclidean distances and the Ward linkage method because of its robustness with outliers, in order to create well-balanced clusters with small variances (Ward, 1963). The quality indices of the clusters were calculated and compared with the standardized data centered and scaled to unit variance for up to ten cluster solutions to determine the optimal number of clusters.

2.5.1.2 Cluster analysis II (students process and outcome data)

In order to identify structures across all clips, a second cluster analysis was performed using the process variables. This analysis utilized a hybrid two-step cluster analysis approach, combining the variance-based approach of Ward and k-means (Punj and Stewart, 1983). The distances were computed with log-likelihood and the optimum number of clusters was determined using the Bayesian Information Criterion (BIC). To test our hypothesis that certain analysis strategies lead to more accurate results, a cluster analysis was performed on each clip.

2.5.2 Correlation and regression analyses

To understand the relationship between process variables and outcome variables, we conducted correlation and regression analyses. The primary goal was to identify process variables that might serve as a predictor for outcomes. Possible correlations might indicate distinguishable differences between student behavior and outcomes, enabling us to conclude what variables shape and possibly determine students on a learning path with a greater probability of succeeding in terms of the defined outcomes.

3 Results

In an effort to grasp how students approach the assignments, an exemplary analysis is offered as an introductory exploration of student engagement with the analysis of classroom videos. Before comparing the students in between, we try to understand individual differences in the video-viewing behavior by looking more closely at the video analysis metadata and video segments that were frequently watched and repeated.

3.1 Video-based analysis strategies for classroom videos

Compared to more receptively oriented learning activities, the discrepancy between the session duration of the analysis and the effective viewing time of video material is striking in video annotation assignments (see **Table 5**).

In this analysis example (see **Table 5**), a little over 30 min were spent using the interactive functions of the annotation tool, and only about 8 min were devoted to receptive activities.

TABLE 4 Outcome-related measures.

Measure	Description
Count of events	Count of events coded by students
Estimator tendency	Estimation tendency, compared to an experts' rating (overestimation/underestimation)
Count of matched events	The count of events matched, compared to an experts' rating
Percentage of matched events	Percentage of matched events, compared to an experts' rating (coverage of students' events with the experts' rating as agreement score)

TABLE 5 Video analysis example of a single participant (student a07, clip 3).

Video analysis metadata	Values
Count of sessions	3
Count of statements	51
Count of played segments	21
Effective watch-time	7.57 min
Progress according to task (%)	117
Count of revisions	12
Session duration	41.32 min
Count of events	14
Count of matched events	11 (79%)
Count *played*	21
Count *paused*	20
Count *seeked*	0
Count *interacted*	2
Played segments as ordered intervals (re-)watched	315[.]323[,]315[.]337[,]337[.]348[,]317[.]318[,]318[.]336[,] 336[.]346[,]346[.]388[,]388[.]414[,]414[.]431[,]431[.]448[,] 448[.]494[,]494[.]528[,]315[.]327[,]327[.]388[,]388[.]448[,] 448[.]492[,]445[.]448[,]448[.]454[,]454[.]462[,]462[.]464[,]464[.]470

In addition to the process and outcome variables of the analysis presented, the number and order of video segments viewed, provide insights into how students proceed with their analysis. As a result, frequently repeated segments in videos become evident, as well as segments that received less attention. Played video segments also indicate the sequential watch order of time intervals within the video, representing the video-specific navigation and viewing behavior. A larger number of played segments represents a more fine-grained and meticulous analysis than a lower number of segments, which may then cover segments with longer periods.

To understand differences in the viewing behavior displayed by students, we gain a first impression through the respective repeated video segment heatmaps. The following heatmap of repeated segments compares the video-based analysis of a student example (S: a07) with the played segments of the group (G), capped to the specified range of the assignment from second 315 to 490 with a total duration of 175 s in the context of a whole lesson recording (clip 3) (see **Figure 2**).

It is noticeable that this student paid closer attention to the beginning timeframe (315–350) and later portions of the video (445–475), since these segments have more repetitions, but reviewed the middle part less meticulously (see **Figure 2**). However, the group additionally focused on a time period in the middle (395–405), which indeed includes classroom events relevant to learning that were not annotated and thus overlooked by this student. As this data provides some initial indications regarding the hypothesis that there are differences in terms of individual analysis strategies, in particular, more meticulous and less meticulous approaches, we consider the comparison of the entire group below.

3.2 Cluster analysis of heatmap data

To analyze and compare the group of students, the heatmap data of repeated segments for clip 3 was clustered hierarchically. The heatmap data illustrates the repetition of segments played, with individual students displayed in rows and clip time per 5-s period in columns (see **Figure 3**). The colors represent the number of repetitions, while blue colors express none to just a few segment repeats, red colors indicate numerous segment repeats, and green colors repetitions in between. Different patterns visualized within the heatmap serve as a reference point for our hypothesis that there is a difference in how meticulously students analyze the classroom video clips.

The hierarchical clustering shown in the heatmap (see **Figure 3**) is ordered by the similarities of the adjacent elements, to minimize the distances. Clusters at the top contain students with a greater number of repetitions, while clusters at the bottom signal fewer repetitions, as alternatively hinted by the colors of the heatmap.

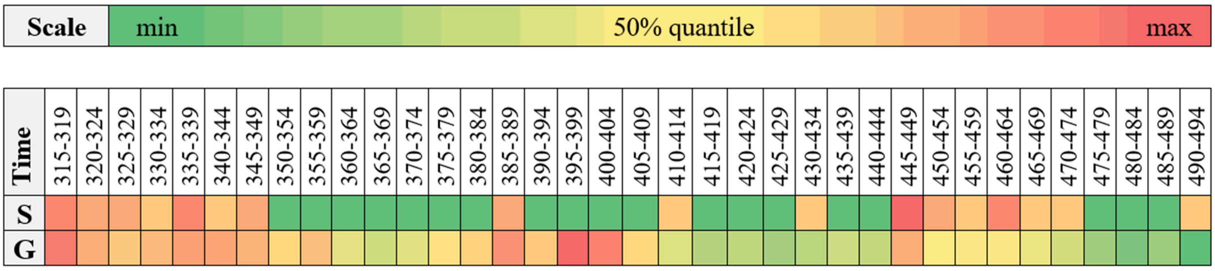
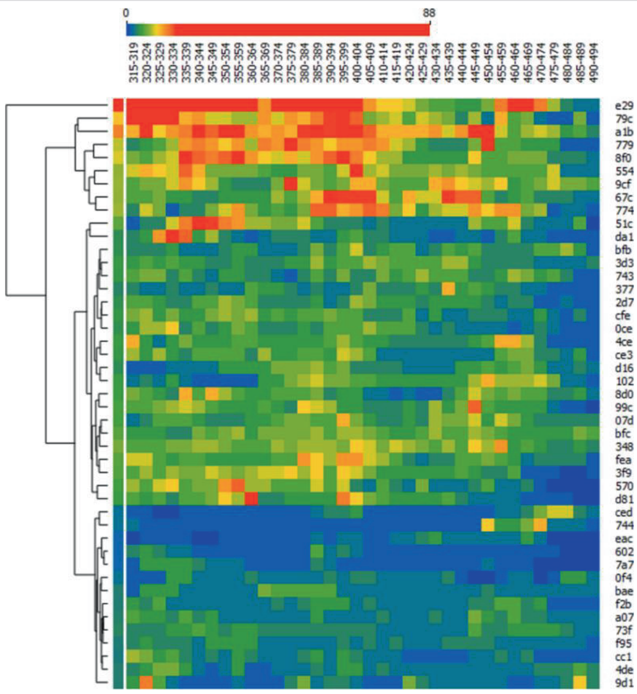


FIGURE 2
Number of repeated segments per 5-second time frame, compared between student a07 (S) and the mean of the group (G), where green indicates minimum repetitions, yellow the 50% quantile, and red is the maximum repetition.

Repeated segments per 5-second and student (clip 3)



Time	Min	Max	Mean	SD
315-319	0	88	6.64	13.29
320-324	1	37	5.84	5.99
325-329	0	26	5.38	4.6
330-334	0	22	5.56	4.62
335-339	1	32	5.96	5.77
340-344	0	43	5.89	7.28
345-349	0	51	5.69	7.68
350-354	1	22	5.13	4.27
355-359	1	25	5.51	4.92
360-364	1	15	4.53	3.35
365-369	1	12	4.24	2.91
370-374	1	18	4.49	3.24
375-379	1	21	5.00	4.41
380-384	1	15	5.24	3.41
385-389	1	20	6.13	4.05
390-394	1	18	5.31	4.08
395-399	1	30	6.67	5.4
400-404	1	23	6.29	4.75
405-409	1	14	4.96	3.61
410-414	1	12	4.27	2.8
415-419	1	10	3.73	2.31
420-424	1	10	3.82	2.38
425-429	1	10	3.44	2.13
430-434	1	11	3.73	2.49
435-439	1	14	3.98	2.86
440-444	1	13	3.82	2.67
445-449	0	37	5.40	5.75
450-454	0	18	4.51	3.52
455-459	1	12	4.44	2.93
460-464	1	18	4.40	3.06
465-469	1	18	4.00	2.8
470-474	0	12	3.60	2.52
475-479	0	8	2.76	2.19
480-484	0	8	2.24	1.71
485-489	0	9	2.49	1.98
490-494	0	5	1.53	1.18

Cluster	Silhouette coefficient	Davies-Bouldin Index	Dunn Index	Calinski-Harabasz Index
2	**0.42**	1.23	0.27	**22.51**
3	0.39	**0.94**	**0.47**	20.10
4	0.19	1.35	0.23	17.63
5	0.13	1.22	0.25	15.48

FIGURE 3
Heatmap and descriptive data presenting the number of repeated segments (Clip 3) per 5-second time frame, showing clusters, with optimal cluster sizes highlighted.

While the Silhouette score and Calinski-Harabasz index favored a two-cluster model, the Davies-Bouldin and Dunn index favored three clusters. The Silhouette scores of two and three clusters were only slightly apart, and both indicated a moderate structure. Since the quality of clusters was lower for a larger number of clusters, only up to five cluster splits were reported here. In conclusion, it is possible to differentiate between at least two groups of students. Those exhibiting high repeating behavior, thus analyzing the video content more meticulously, and those who re-watched video segments less often, signaling that they had not dealt with the video content as meticulously as the other group did. Based on the heatmap data, it also seems salient that later segments were repeated less frequently, suggesting an overall reduction in the intensity of observation toward the end of the clip.

3.3 Comparison of the three video clips

Descriptive data yield insights into process-related variables and their distribution within the group by comparing data from

TABLE 6 Descriptive statistics of process variables.

Process variables	Clip 1		Clip 2		Clip 3		Comparison	
	Mean	SD	Mean	SD	Mean	SD	*p*	*Eta*^{2}
Count sessions	6.14	3.23	6.93	3.53	3.11	1.90	<0.001	0.490[a]
Count statements	102.59	50.78	95.05	41.10	88.64	46.68	n.s.	0.031
Count of played segments	70.44	57.04	74.23	64.76	62.27	53.33	n.s.	0.013
Effective video watch-time	11.95	4.68	15.25	5.80	13.33	7.31	0.014	0.136[b]
Progress according to task (%)	95.14	16.03	112.41	31.01	137.80	61.93	<0.001	0.320[a]
Count of revisions	52.02	19.58	74.80	33.18	28.87	16.26	<0.001	0.550[b]
Count of *played* statements	34.80	19.53	33.84	17.06	31.69	18.21	n.s.	0.011
Count of *paused* statements	37.07	21.86	37.86	19.14	35.62	21.94	n.s.	0.003
Count of *seeked* statements	8.48	11.62	7.39	7.58	6.26	6.89	n.s.	0.030
Count of *interacted* statements	1.89	2.91	1.41	3.85	1.32	2,81	n.s.	0.032

[a]linear trend. [b]quadratic trend. n.s. not significant.

the video clips (see Table 6). This also allows for the comparison of interaction behavior across different video annotation assignments.

3.3.1 Inter-individual differences and process-related similarities

There was a high standard deviation in the count of segments played, the count of revisions, and the count of total statements (see Table 6). Used as a measure for distinguishing meticulous from less meticulous analysts, this deviation supports the hypothesis that video-based analysis is performed with different strategy use, derivable using Learning Analytics as considered. Concerning the technical video-player interactions within the process of analyzing, such as *play*, *pause*, *seek*, differences between the video clips were not significant (n.s.). Similarly, the count of statements and played segments were not significantly different, presumably because of the comparable clip lengths.

In terms of outcome variables, the clips deviated significantly (see Table 7). Students managed to achieve a greater percentage of agreement with experts, with fewer events interpreted in the last clip (clip 3). However, a learning gain regarding the outcome variables can neither be directly inferred nor rejected, based on this data. The data shows students tend to underestimate events overall, compared to experts. Nevertheless, there was an acceptable agreement of about 60% for clips 1 and 3 and about 50% for clip 2 of the students' ratings with the experts' rating.

3.4 Correlations between process- and outcome-related variables

We also performed analyses on the aggregated data of all clips, as well as each clip on its own. By observing significant correlations between process variables in the aggregated data of all clips, we can draw some conclusions about students' consistent learning behavior in the digital environment and video-based assignments (see Table 8). The correlation matrix (see Figure 4) shows relationships between all process variables as well as our outcome variable. The brighter the color within the correlation matrix, the greater the Pearson correlation coefficient. Below, we take a more in-depth look at significant correlations that highlight relationships between the process data.

3.4.1 Students who revisit the activity

Students revisiting the learning activity (count of sessions) also revised their annotations more often than others ($r = 0.323$, $p = 0.030$). One reason for this may be the harnessing of other learning resources, e.g. the content of course sessions, thus leading to a greater extent of revisions afterward. They also engaged with the video content for a longer period (effective watch-time) ($r = 0.420$, $p = 0.004$) and more granular regarding the count of played segments ($r = 0.341$, $p = 0.022$). Students with more frequent revisits also exhibited a greater engagement in terms of statement count ($r = 0.381$, $p = 0.010$).

3.4.2 Students with high engagement

Students engaging with the digital learning environment more frequently (count of statements), thus creating a larger number of statements, displayed a significantly larger effective watching time ($r = 0.723$, $p < 0.001$). Those students tended to show a more meticulous analysis, which was characterized by a video-viewing behavior that was very granular, with a larger count of played segments ($r = 0.758$, $p < 0.001$) and more frequent cycles of playing and pausing the video.

3.4.3 Students with full-screen viewing behavior

Students who switched to a full-screen video-viewing mode more regularly (count of interacted statements) also had a larger number of segments played and thus exhibited more granular viewing behavior ($r = 0.691$, $p < 0.001$). Students who used the full-screen viewing have a moderately larger count of matched events ($r = 0.299$, $p = 0.048$). Moreover, full-screen mode might be more engaging as there was a moderate relationship between the switches to full-screen and the progress ($r = 0.423$, $p = 0.004$) as well as watch-time ($r = 0.572$, $p < 0.001$).

TABLE 7 Descriptive statistics of the outcome-related variables.

Outcome variables	Clip 1		Clip 2		Clip 3		Comparison	
	Mean	SD	Mean	SD	Mean	SD	p	Eta^2
Count of events (experts)	34	0	47	0	62	0	–	–
Count of events (students)	19.36	5.29	25.02	9.97	12.64	4.77	<0.001	0.532[a]
Estimator tendency (deviation between students and experts)	−14.64	5.29	−21.98	9.97	−49.36	4.77	<0.001	0.965[a]
Count of matched events (agreement between student and expert events)	11.02	2.38	11.75	3.73	7.39	2.98	<0.001	0.532[a]
Percentage of matched events (agreement between student and expert events in %)	59.20	13.61	50.00	13.32	60.00	16.03	<0.001	0.324[b]

[a]linear trend. [b]quadratic trend.

TABLE 8 Grouped correlations between variables, aggregated across clips.

Variables	Students who revisit the activity (count of sessions)	Students with high engagement (count of statements)	Students with full-screen viewing behavior (count of interacted statements)
Effective watch-time	$r = 0.420, p = 0.004$	$r = 0.723, p < 0.001$	$r = 0.572, p < 0.001$
Count of played segments	$r = 0.341, p = 0.022$	$r = 0.758, p < 0.001$	$r = 0.691, p < 0.001$
Count of statements	$r = 0.381, p = 0.010$	n.s.	n.s.
Count of revisions	$r = 0.323, p = 0.030$	n.s.	n.s.
Progress	n.s.	n.s.	$r = 0.423, p = 0.004$
Count of matched events	n.s.	n.s.	$r = 0.299, p = 0.048$

n.s. not significant.

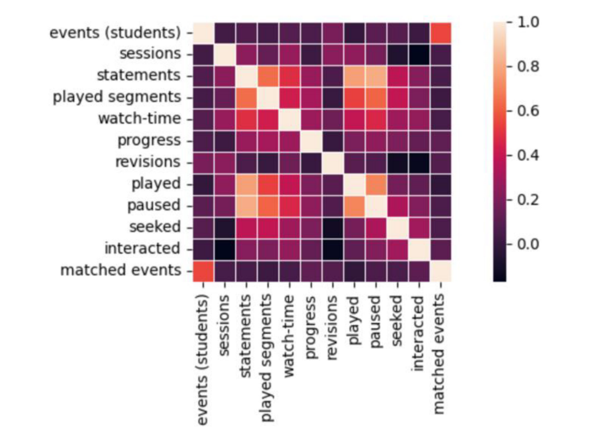


FIGURE 4
Correlation matrix of variables.

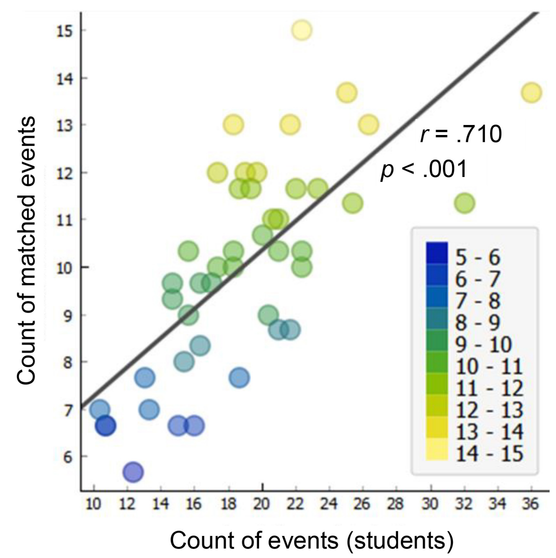


FIGURE 5
Scatter plot between count of events and count of matched events.

3.4.4 Students with a high event count

Aggregated data from all three clips shows that students' event count correlated strongly with the count of matched events with the experts' rating ($r = 0.710$, $p < 0.001$, $R^2 = 0.503$, SER = 1.59) (see Figure 5). This means that a consistent set of their observations matched those of the experts across the clips. With an increasing number of coded events, the rate of matching events remained constant. Even though an increasing number of coded events does not necessarily tell us anything about performance classes the student might belong to, the count of events seems a predictive measure across all clips regarding our outcome variable. As the students display underestimating behavior in general, several factors might contribute to the missing out on events in the classroom relevant to learning.

3.4.5 Correlations with the count of matched events

Considering the count of matched events with the experts' rating as outcome variable, we found weak to strong correlations with process variables (see Table 9). We discovered a strong and consistent relationship between the count of events coded by students and the count of matched events. This connection was present across all video clips and clearly relates video-based analysis strategies to learning outcomes as hypothesized (see Figure 5). Besides this, carrying out a more meticulous video-based analysis was positively associated with better results in terms of matched events with the experts' rating, although a significant relationship could only be determined for clip 3, therefore showing only limited evidence that there is a moderate effect regarding a more granular viewing of the clip and intended outcomes. However, the presence of significant correlations between the process variables and our outcome variable still strengthens our hypothesis that analysis strategies can be differentiated based on their effectiveness and process-related data, though this kind of relationship was not consistently observable within the data of our other video clips. Furthermore, this also indicates that Learning Analytics is indeed capable of uncovering these kinds of relationships to some extent in the first place, allowing for building data-based interventions and adaptive learning support later on.

3.5 Cluster analysis

To test our hypothesis that certain analysis strategies lead to better outcomes, a cluster analysis was performed on each clip, and correlations of the cluster membership with outcomes were investigated. The count of specific statements was not used to form the clusters, because of collinearity with the count of statements. We conducted the two-step cluster analysis and computed the distances with the log-likelihood function. The optimum number of clusters was determined using the Bayesian information criterion (BIC).

The silhouette coefficient as a measure of cohesion and separation was moderate (see Table 10). Cluster membership was positively associated with learning outcomes. However, the relationship was weak and not significant. This suggests that the expected relationship between a more meticulous student analysis and an improved agreement with the experts' rating cannot be concluded from this specific cluster separation, although at least the direction of the correlation corresponds to the expectations. To further investigate the separation and differences between the clusters on a feature basis, we conducted a *t*-test (see Table 11).

The results indicate the clusters differed significantly in various process variables used to constitute these clusters, so that well-separated clusters can be identified. Less meticulous analysts exhibited fewer revisions of annotations (count of revisions), visited the learning activities less often (count of sessions), showed fewer overall engagement (count of statements), and viewed the video only to the extent necessary (progress), without voluntarily including larger teaching contexts, what could otherwise express motivated self-interest or a desire for more in-depth understanding of contexts. The clustering offers an understanding of the features and distinctions among students' video-based analysis strategies, in relation to our research question. It is illustrated that the utilization of Learning Analytics provides insights into whether students analyze classroom videos in a more meticulous or less meticulous manner.

4 Discussion

The aim of this study was to research individual approaches to analyzing classroom videos to promote professional vision of classroom management. In this section, an overview of the study's findings is provided and discussed, addressing the research questions and hypotheses established.

4.1 The learning analytical approach and the role of segments in video-based analysis strategies

Our first hypothesis, investigating the characteristics and differences between students' video analysis strategies, stated that distinguishable video analysis strategies can be derived using Learning Analytics while students analyze a classroom video using an annotation tool.

We showcased that Learning Analytics can reveal insights into learning processes in the context of video-based assignments to promote a professional vision of classroom management and allows for deriving and distinguishing video-based analysis strategies from process-based data. By observing granular video-watching behavior during the analysis of classroom videos, we could uncover that students exhibit varying approaches to video-based analysis, demonstrating strategies for coping with the teaching complexity featured in the respective video segments. Clusters emerged from the examination of segment repetitions, encompassing less meticulous and meticulous approaches to video-based analysis, representing the notable deviation in segment repetitions between individuals (see Figure 3). These clusters bear resemblance to findings in other studies, where clusters were formed based on student engagement with videos in different contexts (Kizilcec et al., 2013; Lust et al., 2013; Mirriahi et al., 2016; Khalil et al., 2023). The segment analysis revealed sequential viewing behavior, suggesting that students who rewatched fewer video segments showed a less meticulous and superficial engagement with the video content, compared to more meticulous analysts who exhibited a fine-grained viewing behavior, paying closer attention to several parts of the video content.

We pointed out indications that observing segment repetition and sequential viewing behavior can help identify patterns and infer conclusions about the viewer's engagement with the video content. These conclusions might be suitable for providing adaptive learning support during the analysis in the future, for example, cueing specific video segments that were missed but contain important classroom events. The results also revealed several potential follow-up research topics to further investigate this type of data, such as examining student behavior concerning a more content-oriented perspective of the video segments, like the difficulty (Li et al., 2005) or concrete classroom events that are observable, for example, by using the experts' rating as an underlying semantic content structure for the video. Incorporating segment data is a fundamental aspect when embarking on the initial stages of creating a personalized learning experience. By leveraging the acquired heatmap data, it becomes possible

TABLE 9 Clip-wise correlations between process variables and outcome variable (count of matched events).

Variables	Clip 1		Clip 2		Clip 3		Aggregated across all clips	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Count of events (students)	0.578	<0.001*	0.708	<0.001*	0.756	<0.001*	0.710	<0.001*
Count sessions	0.021	0.894	0.188	0.222	0.195	0.204	0.119	0.440
Count statements	0.061	0.694	0.130	0.402	0.319	0.035*	0.179	0.246
Count of played segments	0.050	0.751	0.071	0.649	0.310	0.041*	0.262	0.085
Effective video watch-time	0.230	0.136	0.055	0.722	0.290	0.056	0.158	0.305
Progress according to task (%)	0.049	0.751	−0.027	0.861	0.188	0.222	0.131	0.397
Count of revisions	0.132	0.394	0.326	0.031*	0.190	0.208	0.194	0.206
Count of played statements	0.043	0.782	0.055	0.722	0.288	0.058	0.113	0.465
Count of *paused* statements	0.094	0.542	0.084	0.587	0.314	0.038*	0.187	0.224
Count of *seeked* statements	0.038	0.806	0.256	0.093	0.063	0.661	0.074	0.632
Count of *interacted* statements	0.211	0.169	0.129	0.405	0.315	0.037*	0.299	0.048*

*Significant correlation.

TABLE 10 Clip-based clustering on process data.

Cluster metadata	Clip 1	Clip 2	Clip 3
Cluster 1 (less meticulous analysts)	$n = 28$	$n = 38$	$n = 38$
Cluster 2 (meticulous analysts)	$n = 15$	$n = 6$	$n = 6$
Silhouette coefficient	$sc = 0.5$	$sc = 0.5$	$sc = 0.6$
Correlation of cluster membership with count of matched events	$r = 0.061, p = 0.695$	$r = 0.135, p = 0.383$	$r = 0.217, p = 0.156$

TABLE 11 Cluster separation: differences within process data (cluster means).

Process variables	Clip 1		Clip 2		Clip 3	
	Cluster 1	Cluster 2	Cluster 1	Cluster 2	Cluster 1	Cluster 2
Count of sessions	4.86	8.67*	6.79	7.83	2.95	4.17
Count of statements	75.54	164.47*	88.24	164.33	74.53	199.50*
Count of played segments	36.54	141.73*	63.13	225.5	46.58	206.83*
Effective video watch-time	9.72	16.12*	13.62	28.29*	11.26	26.73*
Progress according to task (%)	96	100.00*	102.89	194.83*	121.05	304.5
Count of revisions	45.64	67.80*	71.87	98.83	25.26	68.50*

*Significant differences between the clusters.

to provide customized feedback that aligns with individual student behavior.

4.2 Types of video-based analysis strategies

To examine the characteristics and differences between students' video analysis strategies, our second hypothesis stated that students exhibit individual strategies that can be discriminated into meticulous and less-meticulous approaches to analyzing classroom videos.

The exploration of the played segment data revealed that a group of students analyzed the videos in a fine-grained manner, thus using a more meticulous strategy to reveal the events relevant to classroom management, while another group explored the content on the surface, with fewer repetitions of video segments. A further qualitative evaluation seems desirable, given the moderate quality of the cluster (see **Figure 3**).

In terms of overall engagement, the number of repetitions decreased throughout the clip, implying a reduction in the intensity of observations by students toward the end of the clip. This result might indicate a decrease in attention or motivation, according to similar findings in the video-viewing behavior of students within other contexts (Guo et al., 2014; Kim et al., 2014; Mayer and Fiorella, 2014; Manasrah et al., 2021). Another reason for such an analysis pattern could be the lack of self-assigned time spent on the activity in a self-regulated setting, or other duties, since the work on the video-based assignments could be interrupted at any time.

A correlation of the segment repetitions with the outcome variables was examined only indirectly through the number of segments played. It cannot be concluded, based on the played segment data, that more segment repetitions are associated with better learning outcomes, as this was not part of the study. Within other contexts, it was found that rewatches of (lecture) videos supported memory recalls and had a positive effect on subsequent exam scores (Smidt and Hegelheimer, 2004; Patel et al., 2019). Further research seems necessary to investigate this type of relationship in the context of acquiring professional vision, not least because an alternative explanation is that some students may simply have taken longer than others to recognize relevant events in the video and thus have displayed more segment repetitions. This reasoning aligns with findings for lecture videos, either where less frequent views indicated high-achieving students and a high number of repetitions indicated low achievers (Owston et al., 2011), or where students struggled with the difficulty of the video content (Li et al., 2005, 2015). This kind of observation has to be examined carefully, as interesting and confusing parts of a video both lead to a peak in repetitions (Smidt and Hegelheimer, 2004). As these results were found in the context of videos presenting the content rather than being the subject of learning, such as lecture videos, they cannot be applied elsewhere without further adaptation, but reveal possible research topics for our field of interest. With recourse to Kalyuga (2009) and Costley et al. (2021), another explanation could be that strategic use entails additional cognitive load.

4.3 Analysis strategies compared across different classroom videos

The use of Learning Analytics revealed inter-individual differences in analyzing classroom videos. Considering the process variables, students showed process-related similarities in the choice and technical nature of video-based analysis strategies across the three video clips, but also inter-individual differences, confirming the hypothesis that students could be divided into different groups concerning the pattern of their applied strategies. The high deviation between process variables indicates differences in engaging with the videos (see **Table 6**). It is not surprising that there were non-significant differences between process variables across the clips, and we did not expect to find any in the first place. The similarity in lengths of the video clips is one possible factor for the lack of significance. It may be the case that analyzing clips of the same length simply leads to similar characteristics of the process variables about the technical interaction behavior with the video player. Another possible explanation is that students' individual strategy use did not change over time, and thus these students showed consistent analysis behavior in different video-based assignments. In this case, the non-significance would be roughly as expected.

The data also shows that students tend to underestimate events overall, in comparison to experts (see **Table 7**). Underestimation of events can have several causes. The events varied in number and difficulty between the clips, for example, because multiple events overlapped and occurred at the same time. In alignment with knowledge about the acquisition of professional vision as outlined in the introduction, students might have spent time noticing irrelevant events, were simply not yet able to notice the relevant ones in strict comparison to the experts' rating, showing a lack of expertise in observing specific events (van den Bogert et al., 2014), or simply may not have had or taken enough time to identify all the noticeable events. In order to determine if certain types of events are being overlooked, further research could involve analyzing events at a content-level, considering the present absence of data on the difficulty of observable events.

4.4 Relationships between process- and outcome measures

To examine what distinguishes successful from less successful video analysis strategies, our third hypothesis stated that the strategic use of video-based analysis relates to success in learning.

We have discovered notable correlations among various process variables that represent student behavior, thereby adding further evidence to support the identification of different strategy use (see **Table 8**). Students who revisited the activity more often demonstrated a more nuanced viewing behavior, characterized by an increase in the number of segments played and effective watch-time, although these significant correlations were only weak to moderate. Revisiting the learning activity may indicate the use of other learning resources, such as the content of course sessions, and thus lead to a larger number of subsequent revisions observed. In this case, triangulating other data may prove advantageous in uncovering further explanatory approaches to reveal the learning paths. Students who displayed high engagement or engaged in full-screen viewing behavior showed a notable increase in both watch-time and segments played. This implies a more meticulous analysis, although only the particular type of full-screen interaction showed a weak significant correlation with the count of matched events as the outcome variable, suggesting that full-screen viewing behavior may be beneficial in discovering relevant classroom events. Moreover, full-screen mode might be more engaging, as there was a moderate relationship with the video progress.

The count of events that students observed as relevant for classroom management was a consistent predictor of our outcome variable across all clips (see **Table 9**). The more events a student coded, the more events matched with the experts' rating of events. This means that a consistent set of their observations matched those of the experts across all clips, and that as the number of coded events increased, the rate of matching events remained constant.

Beyond this observation, only clip 3 showed further considerably significant correlations of process variables with outcomes. This might be explained by the fact that the conditions for working on the task were different for clip 3 than clips 1 and 2. While the latter were analyzed at home in a fully self-regulated learning environment, the assignment for clip 3 was conducted within a regular seminar session. Although both the given reference time for each analysis and the intended lack of assistance from the lecturer (faded-out learning support) were identical as contextual conditions, the process variables of the setting that were regulated more by external circumstances, corresponded more clearly to our assumptions in comparison to the setting with no supportive regulation. This suggests a different way of working, such as due to the greater freedom in fully self-regulated environments. Several factors can distract students, compared to attending a regular seminar (e.g. their private schedule, other duties, or time spent or set). By triangulating additional data in the future, these kinds of relationships seem worthwhile to explore.

To examine what distinguishes successful from less successful video analysis strategies, our fourth hypothesis stated that more meticulous video-based analyses relate to a greater agreement between students' ratings and the experts' rating. Within our dataset, we could not confirm that a more meticulous video-based analysis leads to a greater agreement between the ratings of students and experts, as no significant correlation was revealed between the two clusters and students' matched events with the experts' ratings (see **Table 10**). Students with a meticulous analysis of the video clip did not display significantly more matched events than students with a less meticulous analysis. This resulted for all three video clips. However, the possibility of an intended process-based diagnostics still seems a thoroughly plausible addition to this approach, as we found positive but non-significant correlations. Furthermore, findings from other contexts suggest, that patterns of greater engagement are positively associated with learning outcomes (Soffer and Cohen, 2019; Wang et al., 2021) or that a more passive engagement is insufficient for learning (Koedinger et al., 2015).

Investigating the well-separated clusters of meticulous and less meticulous analysts on a feature basis, we found significant differences in various process variables, characterizing students' approaches (see **Table 11**). Less meticulous analysts lacked revisions in annotations, visited learning activities less frequently, exhibited reduced overall engagement, and viewed the video solely to the extent required. The application of Learning Analytics reveals whether students examine classroom videos with meticulousness or lack thereof.

5 Conclusion

In summary, our research highlighted that behavioral data derived from learning processes using Learning Analytics can provide valuable evidence of students' utilization of analysis strategies in such video-based annotation assignments. It was shown to what extent analysis strategies differed, and that students individually exhibited more meticulous as well as less meticulous proceedings during their analyses. The presence of indications suggesting a potential link between a meticulous approach and a greater quality of analysis does not yield conclusive evidence across all videos. It is plausible that there are alternative process variables that hold greater predictive value regarding our chosen outcome variable. Promising further variables could be user-generated or qualitatively determined data that go beyond pure interaction behavior and better represent interrelationships.

As video-based assignments are a popular method for acquiring professional vision, and are frequently used in teacher training, there is a considerable potential for adapting Learning Analytics to gain more insights into the process of analysis and its relation to outcomes. Prerequisites include the use of a video annotation tool and an e-learning standard, in addition to a standardized content structure. They help adapt the method suggested in the didactic design of video-based assignments.

Therefore, the findings of this study have implications for the design and implementation of video-based assignments in courses to promote professional vision. This study sets a prerequisite for the broader goal of creating and establishing an adaptive learning environment, including individual feedback and learning support. Exploring different approaches to analyzing classroom videos to promote a professional vision using a learning analytic approach provides opportunities for a wide range of application perspectives that become conceivable. Gained knowledge of process-related behaviors enables the implementation of learning support that adapts to the needs of learners' analyzing the classroom video, such as providing individual feedback and visual cueing to support developing the ability to notice and interpret classroom events relevant to learning.

Accordingly, we attempted to gain insights into the learning processes involved in developing professional vision by using a digital video annotation tool. Understanding the strategies of video-based learning and distinguishing between successful and less successful strategies will help to create a learning environment that aligns with the students' behavior and pacing displayed during the tasks. Adaptive learning support can be provided, such as cues to take a closer look at a previously neglected video segment or consider overlooked categories for a section, addressing the increasing need to provide more personalized content in e-learning (Sinha et al., 2014). This enhances the learning experience in blended learning formats, where the asynchronous phases often lack individual support and feedback. The discovery of behavioral patterns within the data might serve as a foundation for developing adaptive features in the future. With the heatmap data and knowledge of important video segments, students' attention could be focused on areas of interest, supporting the analysis with visual cues within the classroom videos. Our article offers new perspectives in the field of research related to professional vision and contributes a starting point for further studies, as reported indicators of video-based strategies could be used for predictive analytics of learning outcomes and process-based learning diagnostics for developing the ability to notice and interpret classroom events.

Data availability statement

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

Ethics statement

Ethical approval was not required for the studies involving humans because the aims of the research to improve educational practices did not pose a risk to participants, their rights, or interfere with students' academic progress, as the data were collected in compliance with the law, privacy and data policies, using a pseudonymous identifier and aggregated to anonymize the data. In addition, no sensitive data was collected for this study. All students were adults and therefore able to consent to participate in the study. 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

MO: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review and editing. RJ: Writing—review and editing. MH: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Validation, Writing—review and 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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Eye tracking in a teaching context: comparative study of the professional vision of university supervisor trainers and pre-service teachers in initial training for secondary education in French-speaking Belgium

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This study explores the visual strategies of University Supervisor Trainers (UST) for teachers [Upper Secondary Education Teaching Certification—Agrégation de l'Enseignement Secondaire Supérieur (AESS)] in French-speaking Belgium and the pre-service teachers (PT) they train. It aims to understand how these two groups observe a teaching situation, on video, using an eye-tracking device. The video shows the start of a geography lesson given by a trainee in a primary school class. Three research questions were formulated, examining (a) the actor observed (the trainee, the pupil working groups and 4 pupil profiles present in the scene), (b) the visual strategies used to access these actors, and (c) the visual itineraries when a planning error by the trainee is presented on the screen. To answer, we chose to carry out an analysis based on oculometric indicators (fixing, visit, and first view). The results show that UST and PT focus their attention on the same groups of students. However, they do not do so in the same way. UST adopt visual strategies that are distinct from those of PT, thus aligning their approaches with those of expert teachers in other studies using eye tracking. Within these strategies, we highlight two important points: (a) the emergence of dynamic and floating visual strategies in the UST, characterized by more frequent revisits (significantly validated) and fixations of shorter duration than in PT; and (b) less fixation of UST in observing students who are very active in class compared to PT. Finally, the specific analysis of the UST gaze itineraries at the time of the trainee's planning error reflected both common elements (e.g., teaching tools) and divergent elements (e.g., checking pupils).

KEYWORDS

eye-tracking, visual strategies, trainer-supervisors, future teacher, oculometric indicator

1 Contextualized introduction

In French-speaking Belgium, the initial training of pre-service upper secondary teachers (PT)[1] is provided by the universities as part of the AESS program (Agrégation de l'Enseignement Secondaire Supérieur—Upper Secondary Education Teaching Certification). This 30-credit course includes theoretical courses and practical placements, but its limited duration poses a challenge for University Supervisor Trainers (UST), particularly in terms of developing their practical teaching skills, which takes place over a period of 40 h at university and 60 h on placement in schools (Bocquillon, 2020). The act of teaching is complex and demanding (Wyss et al., 2021). It generates inherent tensions, as it requires mastery of a variety of teaching practices, some of which have proved more effective than others (Bocquillon, 2020), and adaptation to classroom environments which are often characterized by a density of competing and transient information (Lanéelle and Perez-Roux, 2014; Jarodzka et al., 2021).

In response to this challenge, a training methodology based on micro-teaching (in the sense of Wagner, 1998) was designed and implemented by Derobertmasure (2012), then Bocquillon (2020) for three faculties at the University of Mons (Belgium). Using their dual role as trainer and researcher (see Bocquillon et al., 2018 for a summary), these authors have developed a system in which each PT gives a 30-min lesson in front of other PT. The entire lesson is filmed. The PT then discuss a 5-min sequence, which they have selected beforehand, during individual video debriefing sessions with a UST (Duvivier and Demeuse, 2023). During the debriefing, the UST and PT are thus involved in the same process: that of observing and commenting on the lesson extract chosen by the PT. In the sense of van Es and Sherin (2008) this process of observing and then reflecting about it is based on the concept of the professional vision (PV).

The PV of PT is attracting increasing interest from researchers (Jarodzka et al., 2021), whereas the PV of UST remains largely understudied. Yet the observation and analysis of teaching scenes is one of the main activities of UST (Cohen et al., 2013; Wyss et al., 2021). Moreover, understanding what a UST perceives visually can give an idea of what teachers should perceive (Wyss et al., 2021) or, at least, serve to identify "points of interest." Moreover, the UST' practices involve specific features which are sometimes considered opaque (Paris and Gespass, 2001; Awaya et al., 2003) or often taken for granted, often without any attempt being made to describe and analyze them (Zeichner, 2005).

In this context, we aim at deepening understanding of the PV of the UST and PT they train through the micro-teaching methodology. To do this, we set up an experiment in which the UST and PT watched a 7-min extract of a teaching situation, given by a trainee in a real context. This video had the particularity of simultaneously presenting several aspects linked to classroom management (e.g., pupil's[2] conduct) and learning management (e.g., a lesson planning error). The gaze of the UST and PT was recorded throughout their viewing of the recorded performance and broadcast on a monitor using eye-tracking (ET) equipment (GazePoint GP3HD). In accordance with the simultaneous verbal protocol described by Roussel (2017) each participant was subjected to a double viewing session of the video extract. During the first session (viewing A), viewing took place in silence (Figure 1). During the second session (viewing B), the participants were specifically encouraged to verbalize their thoughts, minimizing periods of silence, while watching the video. After watching the extract, each participant verbalized the salient elements, exploring the aspects that had captured their attention. All verbalizations were recorded and later transcribed for analysis.

In this study, we focus on the oculometric data collected during the second viewing. We report on these data in four sections. The first deals with the theoretical framework, discussing the PV in a teaching context and the use of ET as a method of analysis. The second describes the methodology, the experimental method and the sample. The results are presented by research question in the third section. Finally, the conclusion and discussion summarize the study and address its limitations and prospects.

2 Review of the literature and theoretical framework

2.1 Professional vision in a teaching context

Alonso Vilches et al. (2021) point out that training in areas requiring human interaction, such as teaching "*cannot do without taking into account the characteristics of the complex work situations associated with the daily lives of these professionals*" (p. 15). Indeed, teaching is considered to be a complex activity (e.g., Seidel and Stürmer, 2014; Lachner et al., 2016; Jarodzka et al., 2021) which is characterized by the multidimensionality, simultaneity and immediacy of its environment (e.g., Sabers et al., 1991; Doyle and Carter, 2003; Doyle, 2006; Jarodzka et al., 2021; Keller-Schneider et al., 2021). Classroom environments are dense with competing and transient information (Doyle, 2006), which forces teachers to make rapid choices. In every lesson, teachers are faced with dynamic and semantically open-ended situations, where they often do not have all the information they need to make informed and considered decisions (Wyss et al., 2021). Thus, teaching acts under the pressure of time (Wahl, 1991) and forces teachers to reconcile various and sometimes contradictory objectives at the same time. This conflict is illustrated by the questions of whether it is better at a given moment to focus on individual needs or group dynamics, and whether it is advisable in a specific situation to pursue didactic or educational issues (see Helsper, 2002 cited by Wyss et al., 2021).

A teacher's expertise then lies in knowing what to be sensitive to in the classroom and how to interpret the information in order to make pedagogical decisions (e.g., Van Es and Sherin, 2002 cited by van Es and Sherin, 2008; Lachner et al., 2016; Viau-Guay and Hamel, 2017; Keller-Schneider et al., 2021). This "competence" refers to the PV (Lachner et al., 2016; Keller-Schneider et al., 2021).

Developed by Goodwin (1994) and applied to Teaching by van Es and Sherin (2008), teachers' PV is a complex process that encompasses two distinct but complementary sub-processes: selective attention or

1 Future upper secondary teachers are considered to be pre-service teachers and are therefore referred to in this article by the acronym "PT" (for "Pre-service Teacher").

2 In this article, the term "student" refers to those who receive instruction and includes learners at all levels of education. The term therefore includes pupils, students or any individual in a learning context.

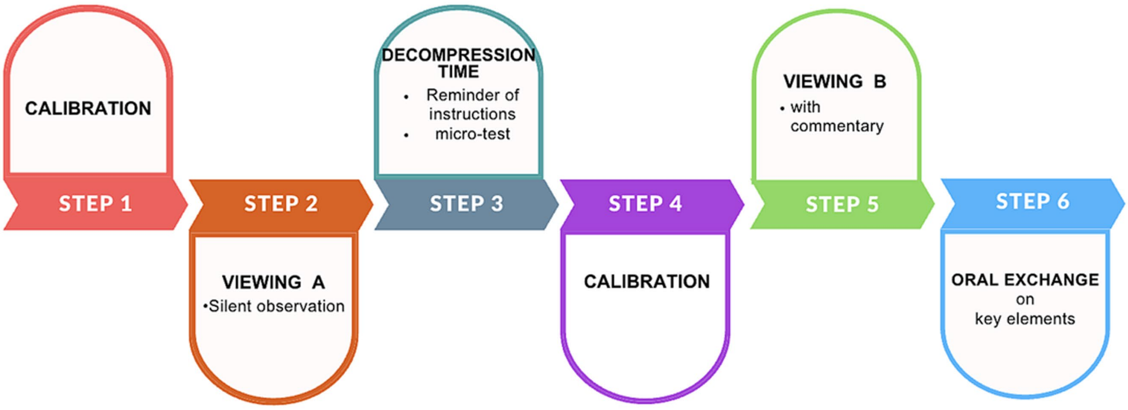

FIGURE 1
Sequences of the experiment.

noticing, and knowledge-based reasoning (e.g., van Es and Sherin, 2008; Seidel and Stürmer, 2014; Vifquin and Frenay, 2018). Keller-Schneider et al. (2021) define attention as the ability of teachers to focus their attention on significant events in the classroom. They consider this skill to be essential for acting adaptively in teaching contexts. This noticing process is closely linked to reasoning, which in turn is influenced by other perceptual processes (Bromme, 1992; Van Es and Sherin, 2002). The reasoning process, for its part, refers to teachers' ability to interpret visual information gathered when observing a teaching situation and to formulate informed judgments to guide their teaching action (Seidel and Stürmer, 2014; Keller-Schneider et al., 2021). It therefore goes beyond simply noticing relevant events and involves reflection and analysis of visual information in relation to teachers' prior professional knowledge. Observation and reasoning are thus two complementary processes: the process of noticing is closely linked to reasoning, which in turn is influenced by other perceptual processes (Bromme, 1992; Van Es and Sherin, 2002). Thus, the two aspects interact closely, influencing the way teachers perceive their classroom environment and make informed and flexible pedagogical decisions (Putnam, 1987; Lachner et al., 2016).

Thus, teachers' PV cannot be considered innate (Stürmer et al., 2017). Rather, it emerges in a way that is closely linked to teaching experience and the way in which this experience is organized and reorganized over time (Lachner et al., 2016). According to Lachner et al. (2016), experienced teachers have a larger and better organized store of knowledge than novices, who rely mainly on explicit and isolated knowledge. This accumulation of knowledge forms a "higher-order knowledge structure" and gives rise to the emergence of "curriculum scripts" that enable teachers to quickly recognize important patterns in the classroom and make informed and flexible pedagogical decisions (Putnam, 1987; Lachner et al., 2016). "Curriculum scripts" comprise a three-step process, as summarized by Seidel and Stürmer (2014): "noticing," "reasoning," and "acting." For this reason, the PV is considered a particularly interesting indicator for describing the knowledge representations that underpin effective pedagogical action in the classroom (Sherin, 2007), which is attracting increasing interest from educational researchers (e.g., Stürmer et al., 2017; Jarodzka et al., 2021).

Finally, the PV is recognized not only as an individual process, but also as a social activity that values certain practices of perception and interpretation (Lefstein and Snell, 2011). This dynamic is a feature of the professional community of teachers, brought about particularly through training (Wyss et al., 2021). Belonging to this community would therefore influence the way in which certain phenomena are viewed and hence the PV of teachers (Vifquin and Frenay, 2018).

2.2 Eye tracking: a method for recording the professional vision

2.2.1 Benefits of eye tracking for capturing the professional vision

According to Laurent et al. (2022) the traditional means of monitoring teacher activity are limited to direct or filmed observation in the classroom, surveys based on questionnaires and participant observation, which is often used in action research projects. These methods have their limitations when it comes to characterizing school events and teachers' practices in a detailed and ecological way.

At present, it is possible to use tools that record these situations in detail, annotate them automatically (Laurent et al., 2022) and define the way in which teachers see and interpret the complex interactions occurring in the classroom (Jarodzka et al., 2021). One of these means is ET, also known as oculometry (Holmqvist et al., 2011). With this technology, it is possible to determine the focus of a person's attention through the tracking of their eye movements (Wang, 2022).

Eye-tracking (ET) technologies are playing an increasing role in educational science to analyze teachers' PV (Lai et al., 2013; Jarodzka and Brand-Gruwel, 2017; Jarodzka et al., 2021). They allow the automatic recording and annotation of gaze behavior, revealing where individuals focus their attention (Laurent et al., 2022; Wang, 2022). These technologies provide a window into teachers' cognitive and decision-making processes, including how they observe and make decisions in the classroom (Stürmer et al., 2017; Burch et al., 2022). A final advantage of ET is the objective quality of the data collected (Laurent et al., 2022). By eliminating certain subjective biases that can result from traditional observation methods, this technology provides highly reliable data for studying PT interactions and teacher behavior in the classroom (Beach and McConnel, 2019). This improvement strengthens the evidence-based education movement and enables educational stakeholders to make more informed decisions about their practice (Saussez and Lessard, 2009; Laurent et al., 2022).

2.2.2 How does eye tracking work?

ET is a method of continuously measuring and recording eye movements as a person interacts with a stimulus in real time, with the aim of knowing what a person has seen (Halszka et al., 2017; Becker et al., 2021; Jarodzka et al., 2021; Wang, 2022) based on detecting the pupil and tracking the corneal reflection (Huang, 2018; Vincent et al., 2018). Two distinct methods are used to measure and analyze people's eye movements. On the one hand, fixed ET is based on stationary devices placed in front of the participant. On the other hand, goggle-based ET involves the use of goggles specially fitted with eye sensors that record data while the subject moves or performs tasks in an ecological environment. For the purposes of this article, we will focus on the fixed ET method.

These elements will be used to establish several indicators (Guerdelli et al., 2008; Vincent et al., 2018; Ju, 2019; Cilia et al., 2021; Loignon, 2021) the main ones of which are detailed below. Before listing them, it is worth clarifying the concept of Area of Interest (AOI). The AOI designates a specific region or a particular element, called a stimulus, in the image that arouses an individual's attention or interest. The stimulus can be a face, a group of pupils, a bench, a painting, or any other identifiable visual element in the image. The AOI are generally defined by the researcher prior to the analysis, enabling (a) a structured approach to the participant's exploration of the visual presentation and (b) an understanding of how the different areas of interest contribute to the overall understanding of the stimulus presented. When the stimulus determined by the researcher remains motionless on the screen, such as a fixed object like a bench, we use a fixed area of interest, or fixed AOI, which remains static. On the other hand, when a stimulus is in motion, such as a teacher moving around a classroom, we use a moving area of interest, or moving AOI. In this case, the defined area follows the stimulus as it moves, allowing more accurate analysis of visual attention as a function of stimulus movement.

A number of oculometric indicators are regularly used to assess the PV in teaching. Firstly, fixations (Figure 2) are characterized by the state in which the eye is relatively still and fixed on an object of interest (Ju, 2019). During fixations, the brain focusing on areas considered subjectively informative (Huang, 2018). Fixations between 0.2 and 0.9 s have proved good indicators of attention (Meteier et al., 2023). Secondly, saccades (Figure 2) are rapid and brief jumps between fixation points (Ju, 2019), which redirect the gaze toward a new visual target (Loignon, 2021). They are recognized as good indicators of attention, as they testify to the way in which the individual explores and processes visual information, thus providing information on the perceptual and cognitive processes involved in visual perception.

Thirdly, visits are indicators that combine fixations and saccades during a gaze visit to an Area of Interest (AOI) (Kim et al., 2012). Visit duration includes all fixations that occurred during a single visit to the AOI, as well as saccades that occurred between these fixations in the same AOI, until the gaze moved outside the AOI. When the participant's gaze returns to a region, particularly an area of interest, that has already been consulted, this is known as revisiting. This suggests that the individual is paying sustained and prolonged attention to this region of the visual stimulus. Fourthly, the "first view" designates the moment when a person's gaze first lands on a specific element in a visual scene. Fifthly, a blink is considered to be a "measurement error" (Carette, 2020, p. 9) which can occur as a result of the participant blinking, head movement or eye-tracker failure. When a blink occurs, the individual's gaze drifts temporarily downward, resulting in "a temporary absence of *gaze* data." (Ju, 2019, p. 27). These blinking episodes can disrupt the continuity of the eye-tracker recording and limit the accuracy of the data collected.

2.3 Analysis of eye-tracking indicators

Two main analytical methods are traditionally used to explore visual behavior. These methods apply both to still scenes, such as photographs, and to animated sequences, as in our study. The two approaches are global analysis and "chain editing" analysis (Huang, 2018).

Global analysis aggregates the visual fixations of multiple participants to reveal the areas of greatest interest to the participant. According to the total duration of fixations or the number of fixations recorded (Huang, 2018), AOI can be identified in two different ways in an eye-tracking study. Firstly, they can be identified during the preparatory work. In this approach, the researcher determines in advance what the AOI will be on the basis of their research hypotheses, the literature and the aim of the study. They define the specific regions or elements of the visual environment they wish to analyze. Then, during the experiment, the researcher records eye-tracking data specifically for these predefined AOI. Secondly, AOI can be identified *a posteriori*. In this approach, the researcher analyzes the data to identify *a posteriori* the areas that aroused particular visual interest in the participants. This approach allows a more open exploration of ocular behavior and may reveal elements that the researcher would not necessarily have thought about *a priori*.

On the other hand, chain editing analysis focuses on visual scanpaths relative to the AOI, based on the order of appearance of fixations and saccades relative to an AOI (Huang et al., 2021). This makes it possible to identify not only where people look, but also how they visually navigate a scene (Kosel et al., 2021). By analyzing gaze trajectories, it is possible not only to identify the specific points at which individuals fix their gaze, but also, and more importantly, to understand the way in which they visually scan a scene, thus revealing the order and path of their observation. This can provide information about how an individual integrates and prioritizes visual information, which can be particularly informative in educational or training contexts.

Although the first approach is more common (Le Meur and Baccino, 2013) there appears to be no clear consensus as to the preference of one approach over the other. Some studies (Huang et al., 2021) consider these approaches to be complementary, based on the following reasoning: the global method provides an initial overview of the relative arrangement of the results, while the chain editing analysis enables the specific aspects raised by the global analysis to be examined in greater depth.

2.3.1 Verbal protocols

Eye activity cannot capture teachers' internal activity and what they are reasoning about (Wyss et al., 2021). This is why a relatively

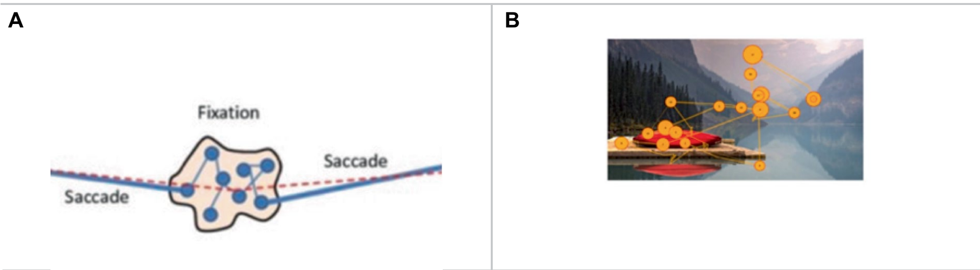

FIGURE 2
Example of ocular fixations and saccades. **(A)** Ocular trajectory made up of fixations and saccades. When an individual focuses on an area of interest, the eye makes micro-movements around this region. These micro-movements are assimilated to fixations. Saccades, on the other hand, occur when attention is directed toward another area of interest. **(B)** Example of a sequence on an image: the numbered circles represent fixations, and the lines illustrate saccades. Adapted from Reyneke, 2019 and cited by Rocca et al. (2023).

common approach (e.g., Ericsson, 2018; Jarodzka et al., 2021) involves combining the analysis of eye movements with verbalizations, as only the combination of these two methods offers complementary and synergistic information, inaccessible with just one of them (Wyss et al., 2021). By combining these two methods, it is thus possible to gain a better understanding of the cognitive processes underlying educational decision-making, the points of attention favored by teachers, and the way in which they integrate their knowledge and experience into their PV (Feldon, 2007).

In practice, verbalizations can be collected in two different ways: simultaneously or *a posteriori* (Roussel, 2017). In the first case, verbalizations are produced in real time while the teaching video is being viewed. This allows for immediate reactions from the teacher regarding what they observe and the thoughts that come to mind as they view the teaching scene (Roussel, 2017). This approach is dynamic and captures the teacher's instantaneous impressions of the teaching situation. In the second case, verbalizations are collected after viewing the video (Roussel, 2017). The teacher is invited to express his or her reflections and retrospective analyzes of what he or she observed while viewing the video. This approach offers deeper reflection and allows the teacher to step back and retrospectively analyze the events and pedagogical decisions they may have noticed. This method can also enable teachers to highlight aspects that they would not have noticed spontaneously in real time (Roussel, 2017).

2.4 The use of fixed eye tracking in the study of the professional vision in the classroom

Exploring teachers' PV through the use of eye tracking is a rapidly expanding area of research. Indeed, while the review by Beach and McConnel (2019) identifies six studies in 2019, for our part, we count at least 28 to date from the Springer, Taylor & Francis, Open Edition, Google Scholar, CAIRN and ERIC databases and *Connected Papers* software. Of these 28 works, 13 of them make use of a fixed eye-tracker. For the purposes of this article, we will mainly focus our attention on the 13 studies that make use of fixed eye tracking (Table 1).[3]

TABLE 1 Studies under review in this article.

N°	Reference authors	Research object
1	Yamamoto and Imai-Matsumura (2013)	Spotting pupil misbehavior
2	van den Bogert et al. (2014)	Distribution of visual attention of classroom events
3	Wolff et al. (2016)	Critical incident
4	van Leeuwen et al. (2017)	Measuring teachers' learning analysis strategies in computer-assisted collaborative learning
5	Goldberg et al. (2021)	Visible commitment from pupils
6	Kosel et al. (2021)	Identification of the visual scanpath patterns and relationship to the assessment of pupil characteristics relevant to learning
7	Minarikova et al. (2021)	Classroom monitoring
8	Schnitzler et al. (2020)	Pupil characteristics in terms of motivational and cognitive engagement
9	Seidel et al. (2021)	Teachers' diagnostic skills when observing pupil commitment
10	Shinoda et al. (2021)	Off-task behavior in the classroom
11	Stahnke and Blömeke (2021)	Event perception in classroom management
12	Wyss et al. (2021)	Critical incident
13	Kosel et al. (2023)	Pupil involvement

2.4.1 Aims of the studies in relation to classroom management and learning

The object of the work (Table 1) can be distinguished in terms of the two types of interventions used by teachers to support pupil learning: learning management and classroom management (Doyle,

3 This choice is based on the observation that mobile ET devices are generally used for self-confrontation of participants with their practices, in contrast to fixed ET, which is mainly oriented toward alloconfrontation. In addition, existing literature (e.g., Duchowski, 2017; Jarodzka et al., 2021) highlights the unique challenges associated with mobile ET, particularly with respect to data processing.

1980). Like two sides of the same coin (Bocquillon, 2020), these two elements make up "the teacher's double agenda" (Shulman, 1986 cited by Bocquillon, 2020).

2.4.2 Learning management: meaning and examples

The teacher's management of learning involves the actions by which teachers take charge of pedagogical content (McKee and Witt, 1990) and ensure that pupils master it (Bocquillon, 2020). This includes implementing appropriate teaching strategies, assessing learner progress and adapting to learner needs and responses. Learning management also includes the teacher's strategies for compensating for a possible planning error - in this sense, a gap or oversight in relation to the original lesson plan.

According to the *Teaching and Learning International Survey* (TALIS) (Quittre et al., 2018), to which the Fédération Wallonie-Bruxelles (FW-B) contributed, teachers in the OECD area devote on average 78% of their time to managing learning, while those in the FW-B devote 70% of their time to it. This significant time allocation highlights the priority given to the active involvement of pupils in the learning process. Among FW-B teachers, more than half (54%) admit that they have difficulty motivating pupils who are not very interested in schoolwork, a rate well above the OECD average of 32%. This problem is particularly pronounced among novice teachers, 61% of whom report experiencing this difficulty.

While the notion of pupil engagement seems to be a major concern among the teachers interviewed in the TALIS survey, it appears to be of lesser concern in the research on the PV. Indeed, only two studies focus on learning management: one by van Leeuwen et al. (2017) which analyzes teachers' strategies for assessing pupil learning, and one by Kosel et al. (2023) which examines visual pathways and their links to the assessment of pupil learning characteristics.

2.4.3 Classroom management, meaning and examples

Classroom management encompasses all the actions a teacher takes to manage his or her classroom, create a climate conducive to learning and set standards of behavior (Bocquillon, 2020), including creating a safe and stimulating environment, monitoring interactions between pupils and setting expectations in terms of discipline and engagement. Most research is based on the analysis of video clips selected to focus on classroom incidents or the behavior of target pupils. Target pupils are those who behave differently from their peers or from what is expected of them (Schnitzler et al., 2020). This may include pupils with specific behavioral challenges that require attention or an adapted pedagogical approach from the teacher. It can also involve, as in the present study or those of Seidel et al. (2021), Van den Bogert et al. (2014), or Wolff et al. (2016), pupils' engagement in the lesson.

The interest in the PV in relation to classroom management is explained by the close link between effective teaching and competent classroom management (Rosenshine and Roberts, 1986). Moreover, classroom management is a particularly significant challenge for less experienced teachers (Nault and Fijalkow, 1999; Dicke et al., 2015). According to TALIS, only a third of teachers feel they have received adequate training in classroom management. In FW-B, 35% of beginning teachers experience difficulties in this area, a figure which is significantly higher than the OECD average of 15% (Quittre et al., 2018).

A larger amount of research has been conducted on classroom management ($n = 11$). Five of these studies focus specifically on pupil engagement (e.g., Schnitzler et al., 2020; Goldberg et al., 2021; Seidel et al., 2021), in particular their calling behavior (e.g., Kosel et al., 2023) or the behavior of particular pupils, the so-called on and off-task behavior in class (e.g., Shinoda et al., 2021). In the latter case, as in the following research, the term "target pupils" is used. "Target pupils" are pupils who behave differently from their peers or from what is expected of them. For example, Wolff et al. (2016) or Wyss et al. (2021) focus on how teachers identify and respond to problematic behavior or significant events that may occur in the classroom. This line of research aligns with that of Yamamoto and Imai-Matsumura (2013), who are specifically interested in how teachers identify pupil misbehavior.

2.4.4 Results of the professional vision studies: university supervisor trainers vs. pre-service teachers

The assessment of the professional vision through fixed ET has not been applied equally to the study of UST and PT. Despite the growing interest in the PV through the lens of expertise (Cortina et al., 2015), UST remain less studied than PT or teachers qualified as experts, as shown in Table 2.

- *Focus on university supervisor trainers*

UST play a key role in the training of PT at university level. By combining the functions of trainer and researcher, UST bring considerable expertise in the field of education, enriching their pedagogy and contributing significantly to the development of training programs. This combination of skills provides them with the specific knowledge, skills and attitudes required for their profession (Ping et al., 2018). The practice of UST has its own specificities, which are sometimes still considered opaque by some authors (Paris and Gespass, 2001; Awaya et al., 2003; Bourke et al., 2018; Hadar and Brody, 2018) or are often taken for granted without much thought to describing, contextualizing and analyzing them (Zeichner, 2005). The professional activities of teacher trainers are varied and go beyond teaching itself (Zeichner, 2005). They include developing the pedagogical skills of PT. In addition, UST collaborate and co-create pedagogical activities with trainees and supervisors. Cohen et al. (2013) complement this view by indicating that, in practical teacher education, a trainer's main tasks are the observation of PT and the provision of constructive feedback during their practical training.

In terms of UST results, Wyss et al. (2021) appear to be the first to study their PV using ET.[4] Their exploratory study looked at how UST ($n = 28$; 18 women and 10 men with between 3.5 and 45 years' work experience) and PT ($n = 28$; 19 women, 9 men; experience unspecified) detected and interpreted critical incidents in the classroom, using both ET and verbal reports. The results (Table 3) suggest that experienced UST have an increased ability to identify critical elements in a complex pedagogical situation, which is reflected in their viewing behavior and verbalizations. The pre-service teachers, although they watched the same video, did not show the same selective attention to the critical incident and did not verbalize as many details.

- *Focus on pre-service teachers*

Pre-service teachers are in the process of acquiring and developing teaching skills, seeking to integrate educational theories and classroom practice. They are learners, often engaged in processes of reflection

4 A second study of trainers was conducted by Kaminskienė et al. (2023). However, it is important to note that this study used an eye-tracking device using glasses, which led to its non-inclusion in this article.

TABLE 2 Double-entry table: distribution of participant groups in the studies included in the review (symbolized by a cross).

N°	University supervisor trainer	Expert teacher	Novice teacher	Pre-service teacher
1		X		
2		X		X
3		X		X
4			X	
5				X
6		X	X	
7		X		
8				X
9		X	X	
10		X		X
11		X	X	
12	X			
13				X

The level of experience of the participants (all school levels combined) refers to Huberman's model (1988). The category of pre-service teachers' (PT) includes studies of teachers in training. By "novice teachers" we mean teachers with up to 3 years' experience. Experienced teachers are those with at least 4 years' experience. Finally, the category of University Supervisor Trainer (UST) includes supervisors involved in initial teacher training at the University.

TABLE 3 Full results of the study by Wyss et al. (2021).

Category	Observations by Wyss et al. (2021)
UST vs. PT viewing behavior	The UST showed significantly different viewing behavior to the pupil teachers. They showed more fixations and a longer total fixation time on the key character in the video
Critical incident response	Analysis of the verbalizations revealed that the UST were more likely to identify and verbalize "critical incidents" in the video. This is in line with expectations and highlights their previous professional experience and increased professional knowledge
Importance of experience	The UST, because of their experience, were able to identify the relevant events in the video more accurately, whereas the pupil teachers did not identify these critical incidents as precisely
Selective attention	Six UST demonstrated a selective focus on the critical incident, neglecting irrelevant elements while maintaining an overall view of other classroom activities

and adaptation to improve their teaching. They differ from novice teachers, who are new to the profession, and expert teachers, who not only have more knowledge, but also a more elaborate and coherent organization of this knowledge, adapted to the situations they encounter (Lachner et al., 2016).

In terms of previous work (Table 2), three studies are listed that were based on designs that compared the outcomes of PT with those of expert teachers. Expert teachers ($n=8$) were studied alone ($n=2$) or in combination with novice teachers ($n=3$) and PT ($n=3$). The results of these studies highlight systematic differences between experienced and less experienced teachers in terms of the PV. For example, six studies (e.g., Yamamoto and Imai-Matsumura, 2013; van den Bogert et al., 2014; Wolff et al., 2016) report that compared to expert teachers, PT may have difficulty allocating their attention optimally, sometimes concentrating on less relevant elements. This tendency may have implications for their ability to manage classroom dynamics effectively. In contrast, Shinoda et al. (2021) found that expert teachers focus more on pupils engaging in off-task behaviors in the classroom, and do so with greater frequency than pre-service teachers. This study highlights a marked differentiation in the way in which experienced teachers and teachers in training perceive and respond to disruptive pupil behavior. Finally, van den Bogert et al. (2014) highlighted the difficulties faced by PT in identifying critical incidents in the classroom compared with experienced teachers. Expert teachers focus their attention more on relevant information in the classroom, enabling them to allocate their attention effectively to the demands of supporting teaching and learning processes (Stürmer et al., 2017; Kosel et al., 2023). Expert teachers also monitor pupils more regularly, whereas PT show greater variability in the frequency and duration of their eye movements (Yamamoto and Imai-Matsumura, 2013; Wolff et al., 2016; Stürmer et al., 2017; Kosel et al., 2023). In addition, expert teachers are able to process visual information more quickly than teachers in training (Van den Bogert et al., 2014; Wolff et al., 2016; Kosel et al., 2023). They also focus more often than PT on information relating to classroom management, indicating greater sensitivity to this essential aspect of teaching (van den Bogert et al., 2014; Wolff et al., 2016). Finally, Yamamoto and Imai-Matsumura's (2013) study suggests that expert teachers' fixation time is more individual compared to PT and is aimed at identifying aspects relevant to learning processes in pupils.

2.4.5 Key points from the studies reviewed

The studies on the PV using fixed ET are uneven in terms of aims and population studied. Most of them focus only on classroom management, to the detriment of learning management or the two concepts, which are nevertheless reported as complementary. In almost half of the cases, the teachers whose PV was studied were experts whose results were often compared with those of PT or novice teachers. The studies found that the visual strategies used by inexperienced and experienced teachers differed. This suggests that, with experience, teachers are able to pick up relevant visual cues from video recordings of authentic lessons (e.g., Yamamoto and Imai-Matsumura, 2013; van den Bogert et al., 2014; Wolff et al., 2016; Wyss et al., 2021) and interpret them appropriately (e.g., Wolff et al., 2015, 2016; Wyss et al., 2021). Therefore, Stürmer et al. (2017) and van den Bogert et al. (2014) suggest that it is important for PT to develop the ability to allocate attention efficiently and process relevant visual information quickly. Furthermore, research on the PV of UST is scarce and still exploratory in nature. Where it exists, it also points to differences between the ways in which UST and PT observe and reason about instructional situations.

3 Methodology

3.1 Hypothesis, research questions, and method of analysis

Considering key points, the present study deliberately focused on UST and PT. Following Wyss et al. (2021), the aim of the present study was to investigate differences between the PV of UST and PT using ET in a laboratory context by viewing a video sequence. UST are recognized as experts in teaching, given their dual skills stemming from both their substantial experience in the field of education and their active involvement in research. This unique expertise gives them an in-depth perspective and nuanced understanding of educational practice. In this regard, the hypotheses of this study treat UST as expert teachers. Three research questions were formulated.

- Research question 1:

1.1 What are the specific elements that UST and PT focus on in relation to the actors in the video?

Considering that attention is more restricted in PT, we expect UST to observe a larger number of elements, including the on-screen trainee and groups of pupils, compared to PT (Yamamoto and Imai-Matsumura, 2013; van den Bogert et al., 2014; Cortina et al., 2015; Stürmer et al., 2017). To do this, several fixed zones were identified on the groups of pupils and a mobile AOI on the trainee (see Section 3.3).

1.2 Do the UST pay more attention than the PT to pupils exhibiting off-task behavior, with the PT being more interested in pupils participating positively in the lesson and in what the teacher is doing in the video?

Considering that UST focus on information relevant to classroom management while PT pay more attention to the conduct of the lesson through pupils who participate or are positive about the lesson (Pupil 2) (Cortina et al., 2015; Wolff et al., 2016; Stürmer et al., 2017), we expect UST to pay more attention to off-task pupils who might disrupt the smooth running of the sequence (Student 1, Pupil 3, Pupil 4). To this end, moving zones were created on the trainee and several target pupils (named E1, E2, E3, and E4). Zones E1, E3, and E4 correspond to off-task pupils, while E2 corresponds to a hyper-participatory pupil (see Section 3.3).

1.3 What are the visual strategies employed by UST and PT with respect to the target pupil (named E1, E2, E3, and E4) in the video?

If UST indeed process visual information faster than PT (van den Bogert et al., 2014), we expect that UST eye scanning capabilities are more dynamic than those of PT. To this end, fixed and moving AOI are used to identify target pupils and their actions (see Section 3.3).

- Research question 2:

2.1 When the trainee makes a planning error, what happens to the visual itinerary of the UST? The planning error involves forgetting to form the same groups of pupils as in a previous lesson in order to complete the activity, which causes an interruption in the instructions for the activity during the time needed to re-form the groups (see Figure 3).

Considering that the UST regularly monitor the class (Wolff et al., 2016; Stürmer et al., 2017), we expect the UST to scan the class visually, focusing in particular on the target pupils (named E1, E2, E3, and E4) during the planning error. To address this, the screen is divided into 9 areas of similar size (see Section 3.3).

3.2 Presentation of the experimental medium

Although the extracts viewed on an ET are generally of short duration, we believe that a longer extract offers a more faithful representation of the complexity of the teaching environment and the interactions between the teacher, the pupils and the school environment (Jarodzka et al., 2021). For this reason, we chose a 7-min video extract representing an authentic geography teaching scene filmed in a class of 10-year-old pupils (elementary school). The sequence is filmed in a single shot without moving the camera (Figure 4).

We opted for the presentation at the beginning of the lesson because, in accordance with the observations of de Peretti and Muller (2013), the beginning of a lesson sets the "tone" for the whole session. This phase also involves many classroom management processes (Bourbao, 2010) that are independent of any subject. This allows us to explore essential aspects of teaching practice that go beyond the simple transmission of knowledge and therefore encompass a series of professional gestures (Bocquillon, 2020). In fact, with reference to Bourbao's (2010) categorization, each of these moments in the lesson can be clearly defined with specific time intervals (Figure 3).

The composition of the class (Figure 4) is as follows: the trainee (I) is on the platform, while the pupils are divided into several working groups. A large group of 10 pupils is positioned to the left of the screen. Two groups of 4 pupils are in the center of the video. A few pupils also appear on the right-hand side of the screen until they are put together for group work (at 3′49″), when they all leave the frame. Among the pupils in the 4 groups who are still on the screen, some stand out before the work begins (at 3′49″; Figure 3) and are identified: pupil E1 can be both involved in the task and sometimes off-task, as when he throws a paper ball,[5] pupil E2 actively participates in answering questions and gives a demonstration next to the trainee on the platform, pupil E3 is off-task (she is drawing a dragon), and pupil E4 arrives late. Each of these events is characterized by its particular dynamic and a specific duration during which it can be observed in the observation window (Table 4).

3.3 Data collection method

Research questions require a holistic approach (Huang, 2018; see Section 2.2). To this end, we superimposed several levels of fixed and mobile AOI. The AOI were identified on the basis of preparatory work by 3 independent coders. In order to determine the visually distinct and salient events in the video, these three coders (1) viewed the video without sound, (2) viewed the video with sound, (3) viewed the video with a mask revealing only one part of the screen at a time. Based on the elements observed, each coder created a timeline in which they targeted events considered important (for example, the target pupils). The comparison of these events (intercoder fidelity of 84.34%;[6] Cohen's Kappa coefficient of 0.71) was used to determine the AOI, which we describe in detail below.

5 In this article, it should be noted that pupil E1 is likely to display a variety of disruptive behaviors. Each of these behaviors has been cataloged and designated as a "Target of Interest" (TOI), i.e., a specific point of interest for observation and analysis. Among these TOI, the paper ball was identified as the shortest behavior in terms of duration, as shown in Table 4.

6 The percentage of agreement was determined using the following formula: number of agreements/(number of agreements + number of disagreements) × 100 (Jansen et al., 2003 cited by Bocquillon, 2020). We have established a threshold of 80% as the satisfaction criterion, in accordance with Miles and Huberman (2003).

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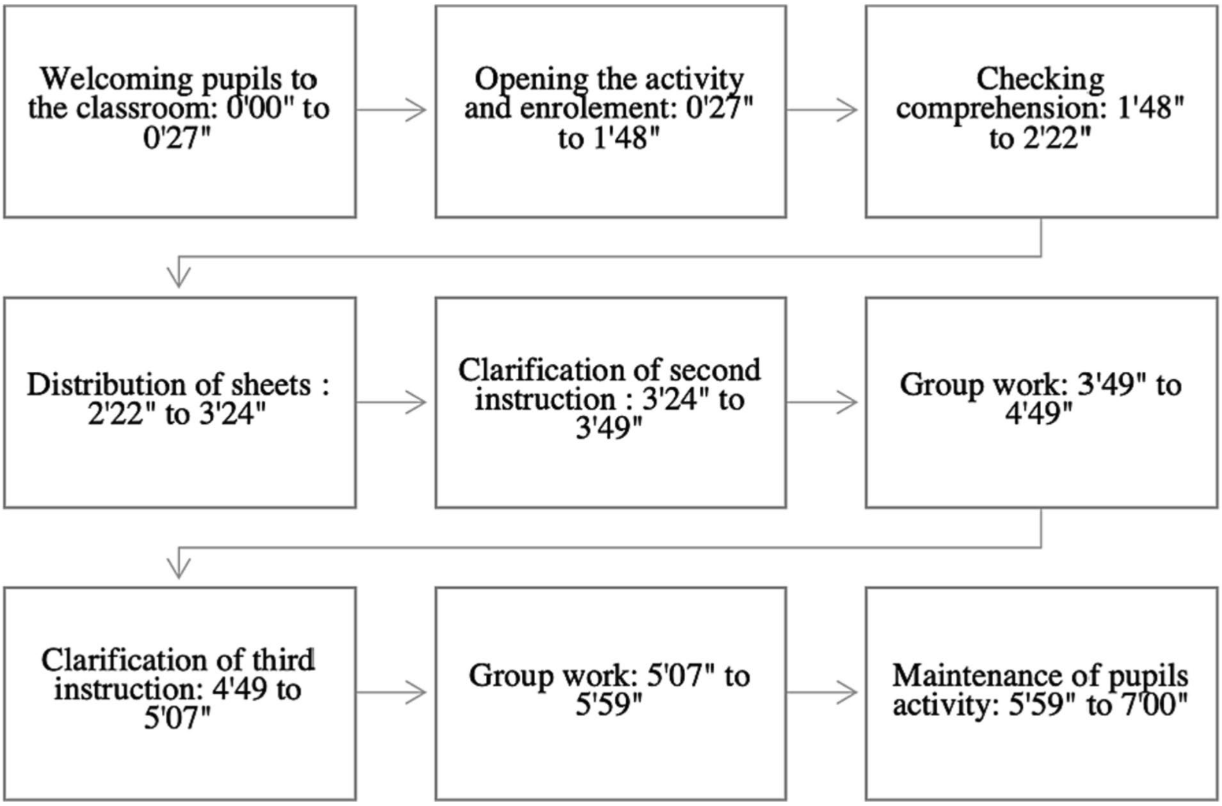


FIGURE 3
Course sequence based on Bourbao's (2010) categorization.

FIGURE 4
Composition of the class in the video extract. (I) trainee giving the lesson, (E1) pupil throwing a paper ball; (E2) very involved pupil; (E3) off-task pupil; (E4) pupil making a late arrival.

More specifically, we first subdivided the screen into 36 fixed AOI of equivalent size, which were then grouped into 9 AOI of similar size (level 1) (see Figure 5). These nine AOI are used to answer the second research question concerning the trainee's planning error. During the period when this error is displayed on the screen, each zone is identified as follows: zone 5 encompasses the teacher's position, with a partial extension into the lower part of zone 2. The other zones are dedicated to the environment in the video (zones 1, 2, and 3) and the pupils (zones 4, 6, 7, 8, and 9).

TABLE 4 Observation window for events in the video.

Event	Start of event	End of event	Observation window duration interval
E1 action	0′35″	0′38″	0′3″
E2 action	0′40″	1′56″27‴	1′16″
E3 action	0	2′54″45‴	2′54″
E4 action	0′26″	0′50″	0′24″

Secondly, we established several fixed AOI on the groups of pupils (left group, middle group, front group) and the environment (left board, middle board, poster, door, etc.) (level 2). Because of its dynamic nature, a mobile AOI was defined throughout the video for the trainee.

Thirdly, moving AOI were defined for the target pupils (E1, E2, E3, and E4) in order to capture their movements (for example, when they get up and leave their seats) (level 3). This was particularly necessary for E2 when he stood up and climbed onto the platform (6-s movement) and then returned to his seat (7-s movement) and E4 when she walked to her seat (3-s movement). Apart from these moments, the size of the AOI was relatively similar (we framed the upper body and head of each pupil).

In order to compare the visual strategies of the PT and UST in our sample on these target pupils, we carried out an equality of means analysis (*T*-Test). Specifically, 12 equality of means analyzes were carried out, taking into account, for each group (UST / PT), the moving AOI of the target pupils (E1, E2, E3, E4) throughout the video and three oculometric indicators: time to first view (in seconds), fixation time (in seconds) and number of (re)visits (occurrence). Here we have considered the moving AOI on the target pupils to be identical despite the movements of E2 and E4, considering that this bias may have affected all the participants in the same way and that the time when E2 and E3 are moving remains relative to the whole of the sequence. Statistical tests were carried out using JASP software, maintaining a significance level of 5%.

3.4 Description of the equipment and the eye-tracker

To ensure that the research is both affordable and reliable (Wang, 2022), we opted for an eye-tracker with a maximum sampling frequency of 120 Hz. The device chosen was the GazePoint GP3HD, renowned for its accuracy and reliability in measuring gaze, fixations and saccades, while minimizing data loss (Bai et al., 2022; Cuve et al., 2022). We used the Gazepoint Analysis Professional software, version 4.1.0, to analyze the ET data. This software offers various functionalities, including fixation trajectories to study eye movements and the definition of AOI to analyze specific regions of the screen.

3.5 Stages of the experiment

The experiment took place in a controlled environment specially designed for the research (Figure 6) where participant and researcher faced each other, separated by the eye-tracking equipment. After calibrating their gaze, the UST and PT first watched the video extract in silence (viewing A). During the second viewing (viewing B), they were encouraged to comment on the video by verbalizing their thoughts, with the aim of minimizing periods of silence, in accordance with Roussel's (2017) "simultaneous think-aloud protocols." These verbal comments were recorded simultaneously with the participants' eye movements. For the purposes of this article, we will focus solely on the eye-tracking data collected from this second viewing. Between the two viewings, the participants are allocated a decompression period. During this break, the researcher checks that everything is running smoothly, reiterates the instructions for viewing B, checks the proper functioning of the microphone in collaboration with the participant before recalibrating the participant's view. Finally, each participant and the person conducting the experiment share the most salient observations from the video. The purpose of this phase is to validate the participants' statements, while allowing them to correct or confirm their comments (Mouchet, 2014 cited by Roussel, 2017). The researcher's role is limited to clarifying the elements at this stage of the experiment.

3.6 Compliance with ethical standards

Our research was designed to comply with the ethical guidelines of the General Data Protection Regulation (GDPR; Art. 89.1), as well as the guidelines of the European Data Protection Board (EDPB). This compliance extended to all stages of the research, from the initial collection of visual data to its subsequent analysis. In the case of classroom videotaping, informed consent was obtained from all videotaped participants. In the case of minors, consent was obtained through forms signed by their parents or legal guardians. Special arrangements were made to ensure that children whose parents did not wish them to be filmed remained out of camera range. For the eye-tracking analysis phase, each participant was informed of the complete confidentiality of the filmed content. The data processing protocols were designed to ensure complete anonymity of individuals, both in the images and in the words recorded. Prior to each experimental session, detailed informed consent was obtained, outlining participants' rights regarding data confidentiality, anonymized use of data, and image rights.

3.7 Description of the sample and conditions of participation

The study included two types of participants, 6 UST involved in teacher training [Agrégation de l'Enseignement Supérieur (AESS)—Upper Secondary Education Teaching Certification] (group 1) and 16 PT enrolled in the AESS program during the academic year 2022–2023 (group 2).

Group 1 consists of six UST; five women and one man. Each of them met two acceptance criteria, i.e., having been a UST for at least 2 years and having been a teacher for at least 3 years (all levels combined) since, according to Huberman (1988) teachers' expertise increases from the third year onwards. Their average age was 36. Four of them have a doctorate in Psychology and Education, while two have a Master's degree in Education. Their teaching experience ranged from 8 to 26 years, with an average of 16 years. With regard to their specific

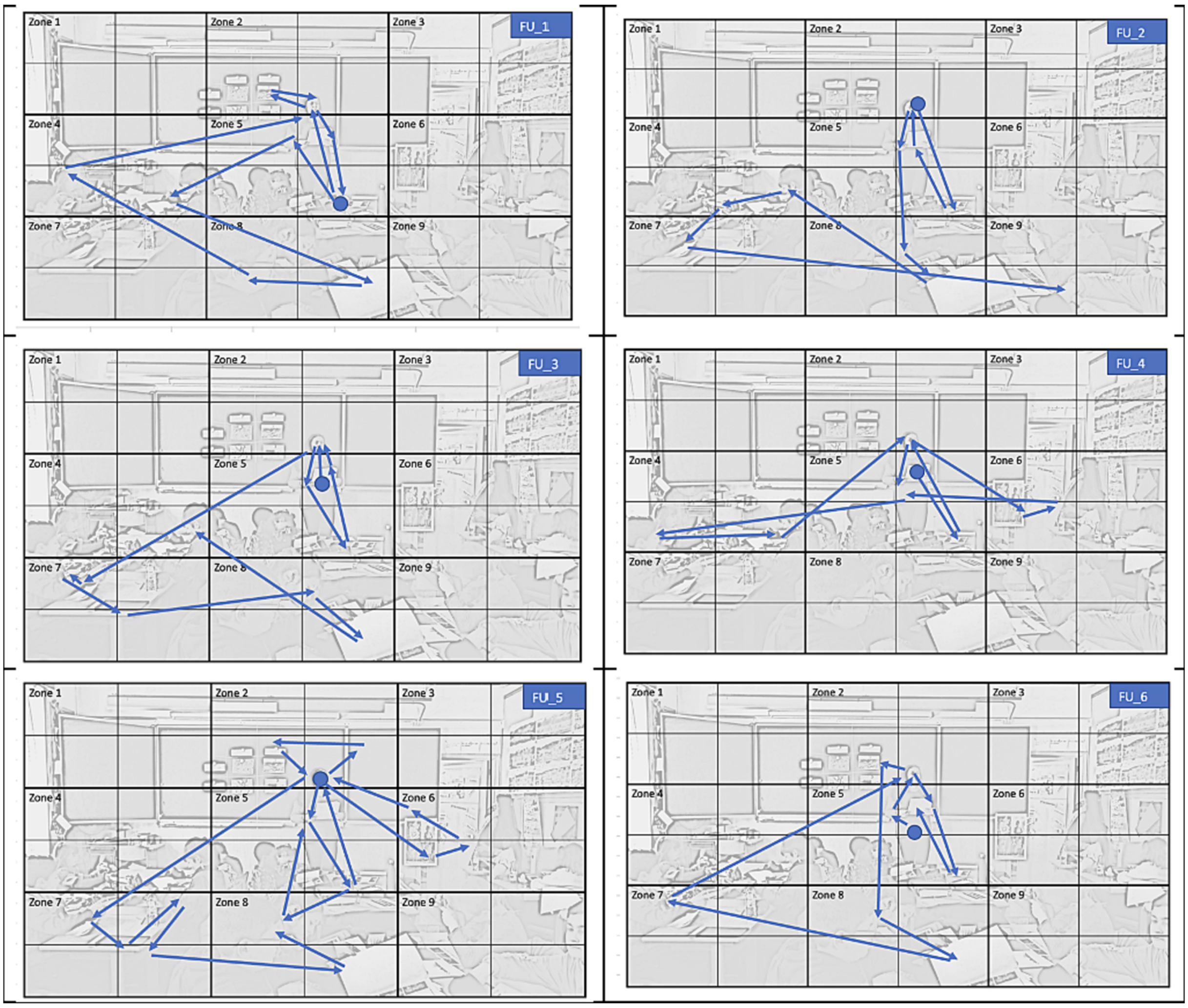


FIGURE 5
Reading direction and order of discovery of the elements with the longest fixations in UST. The beginning of the path is the circle.

experience as AESS UST, the UST had between 2 and 16 years of experience, with an average of 8 years, as UST. Participation in video feedback activities was reported by 5 out of 6 of the UST.

Group 2 consists of 16 PT. Their selection is based on criteria that ensure their active involvement in AESS training, in particular their enrolment in the 'Planning, management and analysis of teaching practices' course. On this basis, 16 PT were selected. Their ages ranged from 22 to 54, with an average of 29. The PT came from the Warocqué Faculty of Economics and Management ($n = 10$), the Faculty of Psychology and Educational Sciences ($n = 4$) and the Faculty of Architecture ($n = 2$) at the University of Mons. Generally speaking, their teaching experience was limited: 10 PT had never taught, and 5 PT had taught for less than 6 months. Only one PT (PT_15) had taught for 204 months.

4 Results

This article focuses on the oculometric data collected during the second viewing session (viewing B; Figure 6).

4.1 Data validation

Data quality verification in our study takes place at two key stages. Firstly, during the experiment itself, with real-time monitoring via the control screen. Secondly, a second check is carried out before the data is analyzed. We have defined three indicators for this check.

The first is based on the work of Chaudhuri et al. (2022) and focuses on the accuracy of the recording. Only records with error-free capture accuracy for at least 70% of their total duration are retained for analysis.

The second is the number of gaze exits and the third is the number of eye blinks during viewing A and B of the extract. This verification steps strengthened our confidence in the results, particularly for UST_5, which showed a high number of gaze exits compared with the average scores for the UST group, both on the first viewing (+3.8 times the average for the other UST) and on the second viewing (+2.6 times the average for the other UST). In this respect, we carried out two checks which enabled us to retain UST_5 in this study. Firstly, we validated the presence and completeness of the eye-tracking data for UST_5 in terms of the number of blinks. Secondly, we observed

FIGURE 6
Experimental condition and data collection stages according to the participant (above the arrow) or the researcher (below the arrow). Participant installation diagram from https://www.gazept.com/faq/.

that the scores for UST_5 remained within a range of average scores for the other UST, with a maximum variation of two standard deviations from the general distribution.

4.2 Research question 1: type of actors observed

4.2.1 What are the specific points on which the university supervisor trainer and pre-service teacher gazes focus with regard to the actors in the video?

For this question, we identified an AOI on the trainee and on each group of pupils who remain in the image (level 2). In order to ascertain which AOI is looked at by the participants and for how long (Ju, 2019), the fixation indicator was used. Table 5 provides data on AOI fixation time, expressed as a percentage of fixation frequency (total AOI time was reset to 100% per participant).

Overall, both groups focused twice as much on the pupils (63.5%) as on the trainee (36.5%). This may be explained by the fact that there is a larger area on the screen dedicated to the pupils than to the trainee. The UST paid slightly less attention to the trainee (33.9%) than the PT (39.0%) while both paid similar attention to the pupils (UST = 26.4%; PT = 26.0%). When we analyze the scores for each group of pupils, we find that attention was distributed in a similar way between UST and PT, with a greater interest in group 1 ($m = 27.5$). The interest in group 1 can be explained (a) by the fact that it includes pupil E2, who is very active, and (b) because the group on this side of the class is the largest. The group of pupils on the left at the back received fewer views, with average scores ranging from 2.5% for UST to 1.7%. This result can be attributed to the fact that some of the pupils in this group are less visible, given the angle of view chosen by the camera filming the classroom scene.

On the basis of these scores, we could assume that there would be no significant differences in terms of mean and dispersion between the two groups of subjects, whatever the area of observation.

4.2.2 Do university supervisor trainers pay more attention to off-task pupils than the pre-service teachers, who are interested in pupils who participate positively in the lesson?

To assess the differences in eye fixation strategies between UST and PT with respect to the target pupils (E1, E2, E3, and E4), a statistical approach based on tests of equivalence of means was employed. This analysis divided the participants into two distinct groups: group 1 comprising the UST and group 2 comprising the PT. Three types of indicators, namely the scores for first viewing, fixation and (re)visiting fixed and/or moving areas of interest (AOI) linked to the target pupils, were subjected to tests of equivalence of means for each group (Table 6).

For the scene involving pupil 1 throwing a ball of paper, the results show that the UST locate pupil E1 more quickly ($m = 336.119$ s) than the PT ($m = 363.196$ s) (Df = 15; $t = 0.682$; $p = 0.505$) and that they stared at the zone for less time than the PT (Df = 20; $t = -1.283$; $p = 0.214$), but returned to it more often than the PT (Df = 20; $t = 1.2$; $p = 0.244$). It should be noted that only UST_5 was able to spot pupil E1 throwing a ball of paper. This finding is all the more interesting given that UST_5 had the highest individual eye-scan speed scores among the University Supervisor Trainers (29 m/s), thus exceeding the average for the group of UST (average of 26.4 m/s). These frequent gaze exits could therefore reflect a rapid and dynamic scanning of the visual scene, which could explain their ability to quickly detect the incident involving pupil E1.

TABLE 5 Average fixation time as a percentage per fixed AOI.

AOI	Fixation time in percent (%)				
	Trainee	Group of pupils to the left (front)	Group of pupils to the left (background)	Group of pupils in the center	Group of pupils in the foreground
Average for UST	33.9	27.9	2.5	17.9	17.8
Average for PT	39	27.1	1.7	16.9	15.3
Overall average	36.5	27.5	2.1	17.4	16.6
Standard deviation UST	6.1	4.3	0.4	8.3	2
Standard deviation PT	6.3	5.6	0.7	5.2	3
Overall standard deviation	6.2	4.95	0.55	6.75	2.5

In the scene involving the hyper-participatory pupil E2, the average results suggest that not only was he spotted more quickly by the PT ($m = 24.346$) than by the UST ($m = 33.525$ s) (Df = 20; $t = 1.297$; $p = 0.209$), but that the PT maintained their gaze on this pupil 1.3 times longer ($m = 24.081$) than the UST ($m = 19.298$) (Df = 20; $t = 1.283$; $p = 0.214$). On the other hand, the UST revisited the E2 zone ($m = 39.16$ revisits) more often than the PT ($m = 32.39$) (Df = 20; $t = 1.2$; $p = 0.244$). Thus, the UST looked at this area for less time and more frequently than the PT. Statistically, the results of the *T*-tests indicate significantly different visual strategies for each of the 3 indicators and in the 2 groups of participants.

As for the scene involving pupil E3 drawing a dragon, the results indicate an average detection time that is twice as fast in the UST ($m = 26.235$) compared with the PT ($m = 54.2$ s) (Df = 20; $t = -2.686$; $p = 0.014$) and twice as many revisits of the area by the UST ($m = 14.987$ revisits) compared with the PT ($m = 6.688$ revisits) (Df = 20; $t = 2.395$; $p = 0.027$). Fixation time remained relatively similar between the two groups [m(UST) = 6.475 and m(PT) = 5.854] (Df = 20; $t = 0.4$; $p = 0.737$), suggesting that the UST observed the off-task pupil with rapid and frequent glances, whereas the PT observed the pupil with longer fixations.

For the scene involving the pupil making a late arrival (E4), the latter was detected at the same time by the PT ($m = 25.59$ s) as by the UST ($m = 24.34$ s) (Df = 20; $t = 0.206$; $p = 0.839$). On the other hand, the PT ($m = 9.029$) fixed their gaze on pupil E4 for slightly less time than the UST ($m = 6.668$) (Df = 20; $t = 0.582$; $p = 0.567$). In terms of revisits, the UST made the most ($m = 12.87$) revisits, in a proportion that is twice that of the PT ($m = 6.008$) (Df = 20; $t = 1.735$; $p = 0.098$).

To answer the question of whether UST pay more attention to off-task pupils than PT, who focus on pupils who participate positively in the lesson, we can consider the characteristics of the pupils in the different scenes.

In our analysis, we identified E1, E3, and E4 as off-task pupils, while E2 is a pupil engaged in the teaching scene. The results indicate that UST tend to identify off-task pupils, particularly E1 and E3, more quickly than PT. However, they maintained their gaze on these pupils for shorter periods. On the other hand, the PT identified E2, the engaged pupil, more quickly than the UST and kept their eyes on him for a longer period of time.

These observations suggest that UST are more attentive to off-task pupils whereas PT focus their gaze on engaged pupils in particular. However, with the exception of E2, it is important to note that these differences are not always statistically significant.

What are the visual strategies employed by the University Supervisor Trainer and pre-service teacher with regard to the target pupils in the video?

The results of the *T*-tests highlight an important finding concerning the gaze strategy adopted by UST and PT. The scores reveal a significant difference between the groups of participants for each type of pupil (E1, E2, E3, E4) with regard to the frequency of revisiting (Table 7). These differences were even more pronounced for the revisiting strategies in the E1 and E3 zones. More specifically, the results suggest that the UST tended to use the "glance" strategy by observing the zones more frequently but for shorter durations. In contrast, PT seem to prefer prolonged observation, i.e., they keep their gaze on the areas for a longer period of time before revisiting. This difference in visual strategy between the two groups of participants is particularly noticeable in the scenes involving pupils E1 and E3.

4.2.3 Research question 2: trainers' visual itineraries at the time of the planning error

The question looks at the visual itinerary of the UST when a planning error by the trainee is displayed on the screen (from 3′24″ to 3′49″ in the video). As a reminder, at this point in the video, zone 5 includes the teacher's position, as does the lower part of zone 2. The other zones are devoted to the video's environment (zones 1, 2, and 3) and the pupils (zones 4, 6, 7, 8, and 9). We chose to focus on exploring the visual itineraries of the UST after examining the percentage distribution of fixation and revisit time for the 9 zones (Table 8).

The results show that UST and PT had an almost identical mean percentage of fixation on the teacher (mean = 59.5% for UST and mean = 61.1% for PT). However, the UST showed a 1.2 times higher rate of revisiting the teacher, placed in zone 5 (mean = 119), than the PT (mean = 98.6). These results suggest that, although both groups paid almost similar attention to the trainee, the UST used different visual strategies, focusing more on 'glances', unlike the PT who made longer, more focused fixations. Our aim is therefore to identify where the UST' attention is focused when their gaze is not directed toward the trainee.

To do this, we chose to explore the models of the UST using Chain Editing analysis (Huang, 2022). For greater legibility, we have manually reproduced the itineraries of the UST (Figure 5). This also allows us to propose an analysis by reading direction and order of discovery following this text.

The results highlight common gaze patterns. In the first stage, signified by the circle, the UST fix their gaze on the trainee giving

TABLE 6 Descriptive statistics for scenes involving the target pupils for the 2 groups of participants.

	Descriptive statistics					
	Group	*N*	Mean	SD	SE	Coef. Var.
E1 1st view	1	5	363.196	4.222	1.888	0.012
	2	12	336.119	87.010	25.118	0.259
E1 fixation	1	5	0.734	0.447	0.200	0.609
	2	12	1.473	2.502	0.722	1.698
E1 revisits	1	5	25.038	3.479	1.556	0.139
	2	12	6.823	6.362	1.837	0.932
E2 1st view	1	6	33.525	21.092	8.611	0.629
	2	16	24.346	11.966	2.991	0.491
E2 fixation	1	6	19.298	12.248	5.000	0.635
	2	16	24.081	5.550	1.387	0.230
E2 revisits	1	6	39.167	19.954	8.146	0.509
	2	16	32.398	7.246	1.811	0.224
E3 1st view	1	6	26.235	18.974	7.746	0.723
	2	16	54.501	22.892	5.723	0.420
E3 fixation	1	6	6.475	3.346	1.366	0.517
	2	16	5.854	3.956	0.989	0.676
E3 revisits	1	6	14.987	8.542	3.487	0.570
	2	16	6.688	6.750	1.688	1.009
E4 1st view	1	6	25.590	13.278	5.421	0.519
	2	16	24.348	12.338	3.085	0.507
E4 fixation	1	6	6.668	5.622	2.295	0.843
	2	16	9.029	9.226	2.306	1.022
E4 revisits	1	6	12.875	12.822	5.234	0.996
	2	16	6.008	6.027	1.507	1.003

instructions, with particular interest in the sheets of paper that the trainee is holding in her hand (UST_3, UST_4), the trainee's face (UST_2, UST_5) to which the gaze quickly moves toward (UST_6), as well as on the table where her belongings are located, including her lesson preparation book and materials (identifiable at the beginning of the lesson) (UST_1). This illustrates their potential preoccupation with the trainee's teaching materials. Next, we observe for 5 UST a series of successive fixations occurring between the trainee's face (UST_1), her hands, the space where she stores her belongings (UST_2, UST_3, UST_4, UST_6). This can be explained by the fact that the trainee is tilting her head or sighing. Three UST look at the sheets on the board (UST_1, UST_5, UST_6). These UST may have turned their attention to the board for several reasons. Firstly, they may be checking whether the trainee was using visual resources or teaching aids to correct her mistake. In addition, the trainee's comment about forming the pupils into groups who had "*taken photos this morning*" may have prompted the UST to examine the illustrations on the board to better understand the context and the instructions given.

Then, when the trainee turned toward the group of pupils in zone 4, we observed a rapid eye movement by the UST in this direction, toward this zone. The movement continues most often into zone 7 where the disruptive pupil (E1) is located for 3 UST (UST_3, UST_5, UST_6). This may be a reminder of the rapid "surveillance" tactics that the UST had implemented for this pupil, perhaps in response to previous behavior or previously established expectations. The other three UST adopted a more focused scanning strategy, concentrating either on zone 4 where the trainee directs her gaze, perhaps in order to observe clearly what is happening there, or on zone 8 (with the group in the foreground) at the moment when the off-task pupil (E2) straightens up to listen.

Beyond these similarities, divergences in the visual scanning of the UST were observed. For example, UST_4 and UST_5 directed their gaze to zone 6 toward pupil E4, showing an interest in his act of distributing sheets and the fact that he is looking for a place to put down the remaining sheets. In addition, UST_5 has a more extended scanning dynamic, suggesting a livelier visual reactivity, as we detailed in research question 1. Furthermore, UST_3 fixes his gaze clearly on pupils E1 and E3, who are known for their problematic behavior at the beginning of the video. This focus may reveal a particular sensitivity on the part of this UST to pupils with behavioral problems within the class. It may also underline their interest and ability to identify and maintain vigilance around key elements of class dynamics. These individual variations are a reminder of the subjective aspect of visual observation and the influence of each UST's own experiences and concerns in determining their eye scan.

5 Discussion, limitations, and outlook

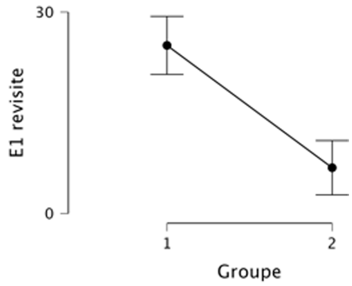
5.1 Discussion

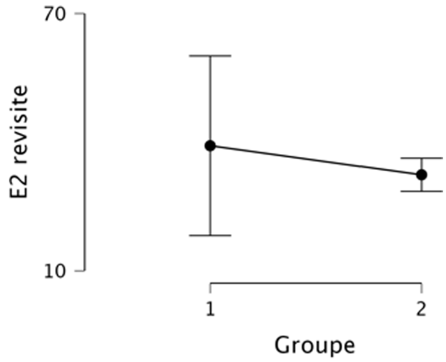
This study aims to fill a gap in the current literature by focusing on the activity of UST and, more specifically, by exploring the process of video observation using ET, while comparing their strategies with those of the PT they are supervising. To do this, we analyzed data obtained from eye tracker-assisted viewings by 6 AESS trainers and 16 PT in French-speaking Belgium. The 7-min video extract shows the start of a lesson given by a trainee teacher. At the same time, each UST and PT was invited to comment on the video in real time and to explain the elements they considered significant. Before analyzing the data, precautions were taken to ensure the quality and reliability of the results. Factors such as the number of gaze exits and the blink rate were examined and taken into account when interpreting the conclusions drawn from this study.

Taking into account recent advances in the literature, three research questions were defined, relating to the object (a) and

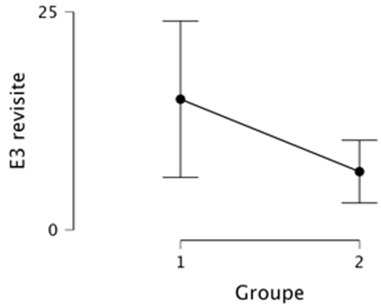
TABLE 7 Number of visits by participant group for E1, E2, E3, E4.

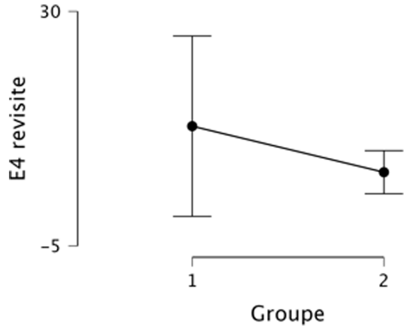
Revisits in E1	Revisits in E2
$t = 5.965$	$t = 1.2$
$p = <0.001$	$p = 0.244$
Df = 20	Df = 20





Revisits in E3	Revisits in E4
$t = 2.395$	$t = 1.735$
$p = 0.027$	$p = 0.098$
Df = 20	Df = 20





Error bars represent 95% confidence intervals.

TABLE 8 Percentage of fixation and revisits by zone.

	Fixation in %								
Zones	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
Average for UST	3.6	50.9	8.0	59.5	117.1	43.3	44.4	53.4	12.3
Average for PT	0.6	21.5	11.9	61.1	126.8	55.6	44.2	49.2	16.0
	Revisits in %								
Average for UT	4.3	92.2	15.5	119.0	206.0	71.3	83.7	96.7	27.3
Average for PT	0.7	59.8	21.1	98.6	179.4	99.7	76.6	59.5	41.4

observation strategies (b), taking into account the four pupil profiles, as well as the visual pathways during the on-screen presentation of a planning error by the trainee (c).

In doing so, the first sub-question questions the actors observed by the participants. In our sample, there do not seem to be any significant differences in terms of mean and dispersion between the two groups of subjects, whatever the area of observation. This tends to run counter to previous work (e.g., Cortina et al., 2015; Wolff et al., 2016; McIntyre and Foulsham, 2018) which indicated that expert teachers focus more on pupils compared to pre-service teachers.

The second sub-question looked at the detection of specific pupil behaviors through 4 target pupils representing pupils who are inattentive (E1), hyper-participatory (E2), drawing (E3), and late (E4). The results showed that in our sample, as in Shinoda et al. (2021) and Wolff et al. (2016), UST tended to identify all these pupils more quickly and particularly pupil E3, who was identified twice as quickly as in PT. In contrast, the PT mainly focused on the actively participating pupil, thus adopting a distinct perspective in their observation compared to the UST group. These differences were determined on the basis of three indicators examined by means testing, namely first sight (faster for UST than for PT), fixation duration (longer for PT than for UST) and revisits (more for UST than for PT). The revisit indicator stood out and the differences were significantly confirmed.

In PT, fixations tended to be of longer duration, accompanied by fewer revisits. The diversity of visual approaches between the groups reflects distinct methods of visual classroom analysis. The UST focus on pupils with disruptive behaviors, suggesting proactive management of classroom dynamics and the ability to quickly detect situations requiring intervention (Wolff et al., 2016). The use of glancing strategies may have the function of optimizing monitoring while maintaining an overview. For their part, PT focus on the hyper-participatory pupil (E2), demonstrating their concern for commitment to learning, as already highlighted by some authors (e.g., Livingston and Borko, 1989; Lipowsky et al., 2007; Cortina et al., 2015; Wolff et al., 2016; Goldberg et al., 2021). It is interesting to note that in the whole sample, only UST_5 was able to visually identify one of the shortest behavioral deviations of E1 - throwing a paper ball. However, UST_5 displayed the highest individual eye scan speed scores among the UST (29 m/s), exceeding the group average (average of 26.4 m/s). These frequent visual movements may suggest a rapid and dynamic scanning of the visual scene, potentially at the origin of their ability to quickly detect the incident involving pupil E1.

The third sub-question focuses on strategies for rapid identification, fixation and revisiting on the AOI dedicated to the target pupils (E1, E2, E3, and E4). Comparative analysis of the results reveals significant differences between UST and PT, particularly with regard to revisiting strategies. In practice, the UST tended to systematically adopt "glance" strategies for all the target pupils, in particular for the disruptive pupil (E1) ($t = 5.965$; $p = <0.001$) and the off-task pupil (E3) ($t = 2.395$; $p = 0.025$), which was not the case among the PT.

For the second research question, we examine how participants focused their gaze when a planning error by the trainee is present on the screen. UST and PT showed similar interest in the trainee, but UST made more revisits toward them. This suggests, again, that UST use "glances," whereas PT focus on longer fixations. The specific analysis of the UST' gaze itineraries also reflected common elements (itinerary centered on the trainee, her personal teaching tools and where she gazed), but also divergent elements (e.g., checking pupils who had shown disruptive behavior at the beginning of the lesson).

In summary, our analyzes converge with Wyss et al.'s (2021) exploratory study in suggesting that UST adopt visual strategies distinct from those of pre-service teachers, thus aligning their approaches with those of expert teachers in other studies using ET. Within these strategies, we highlight two important points: (a) the emergence of dynamic and floating visual strategies among UST, characterized by more frequent revisits and shorter duration fixations; and (b) the divergence in the observation of highly active pupils in the classroom between UST and PT. In addition, our research highlights the importance of classroom management for UST as regards pupils who are not engaged in the task. These elements remind us of the crucial importance of eye scanning in the classroom, an effective professional teaching gesture that is widely recognized (e.g., Bissonnette et al., 2020) and essential for successful classroom management. This concept, first defined by Kounine (1970) as "with-it-ness," involves active visual scanning to ensure adequate attention and support for all students, particularly those less involved. This ability to proactively monitor and respond to classroom behavior distinguishes experienced teachers (Grub et al., 2022). As experts, UST play a fundamental role in the development and transmission of this skill to PT, highlighting its importance in the repertoire of professional teaching gestures.

5.2 Limitations and outlook

The study has certain limitations. Firstly, although the majority of the results appear to be consistent with previous work, we have few direct comparisons with other UST. This limits our ability to fully assess the specificity of visual strategies in UST compared with other UST populations. Moreover, beyond its physiological aspect, the act of seeing and noticing is a dynamic process involving the creation and transmission of meaning in coherence with the communities of practice within which the PT evolves (Wyss et al., 2021). All the UST in our sample are affiliated to the same academic institution. It is therefore possible that their interests, such as classroom management, are linked to the broader concerns of this institution.

In addition, the analyzes were unable to explain certain results in relation to the participants' teaching experience. Although they were tested, the experience variable did not seem to influence visual behavior as such for either the more experienced PT (e.g., PT_15) or the UST (e.g., UST_2). It would therefore be interesting to supplement these results with a qualitative analysis of the comments made during viewing and a multi-case approach to certain results, including those of UST_6. Similarly, our analyzes were not able to differentiate the results according to the training stream of the PT. This limitation may be due to an imbalance in the distribution of the sample across these different streams. This difficulty in differentiating the results may also reflect the fact that the teaching practices remain unknown to the PT, which may indicate a limited familiarity with the specific teaching practices or teaching methodologies within each of the training streams, as already pointed out by Bocquillon (2020).

To conclude, as in the study by Wyss et al. (2021), our study focused on a limited number of UST, which limits the general scope of the conclusions. To improve the understanding of the variability of visual strategies of UST, we suggest collecting more data from a larger and more diverse sample of UST including training supervisors. We also recommend broadening the selection of videos by including a variety of teaching situations of different levels of complexity. In addition, a multidimensional approach, as advocated by Gegenfurtner et al. (2011, 2018, 2023), could be adopted by combining ET with qualitative interviews, observations or neuroimaging.

Data availability statement

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

Ethics statement

Ethical approval was not required for the study involving human participants in accordance with the local legislation and institutional requirements. Written informed consent was obtained from the individuals and minors' legal guardians/next of kin for participation in the study and for the publication of any identifiable images or data included in the article.

Author contributions

VD: Formal Analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing – original draft. AD:

Conceptualization, Funding acquisition, Supervision, Writing – review & editing. MD: Conceptualization, Funding acquisition, 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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Where experience makes a difference: teachers' judgment accuracy and diagnostic reasoning regarding student learning characteristics

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The concept of teacher professional vision suggests that experienced teachers, compared to novice teachers, might be better at making accurate judgments of students' learning characteristics, which can be explained by their advanced reasoning in diagnostic situations. This study examines experienced and novice teachers' diagnoses of different student characteristic profiles: three inconsistent profiles (overestimating, uninterested, and underestimating) and two consistent profiles (strong and struggling). We examined both experienced ($n = 19$ in-service mathematics teachers) and novice teachers ($n = 24$ pre-service mathematics teachers) to determine the extent of differences in their judgment accuracy and their diagnostic reasoning about observable cues when diagnosing student profiles while watching a lesson video. ANOVA results indicate that experienced teachers generally achieved a higher judgment accuracy in diagnosing student profiles compared to novice teachers. Moreover, epistemic network analysis of observable cues in experienced and novice teachers' diagnostic reasoning showed that, compared to novice teachers, experienced teachers make more relations between a broader spectrum of both surface cues (e.g., a student's hand-raising behavior) and deep cues (e.g., a student being interested in the subject). Experienced teachers thereby construct more comprehensive and robust reasoning compared to novice teachers. The findings highlight how professional experience shapes teachers' professional skills, such as diagnosing, and suggest strategies for enhancing teacher training.

KEYWORDS

judgment accuracy, professional vision, student characteristics, expert-novice comparison, noticing, reasoning

1 Introduction

In day-to-day teaching, teachers constantly gather real-time information about their students that enables them to provide personalized instruction. Based on their observations of student learning behavior, they adjust the difficulty of ongoing learning tasks, provide feedback, and assess student performance (Corno, 2008). Judging the cognitive and motivational-affective learning characteristics of students has been identified as a fundamental aspect of teachers' daily professional work: As stated by Shavelson (1978, p. 37), "teachers' estimates of students 'states of mind'—cognitive, emotional, motivational—provide primary information in deciding how to teach" and "during teaching itself, new information can be obtained bearing on the student's current state of mind." In this context, several educational researchers have endeavored to address the question of how accurately teachers can judge student characteristics that are relevant to learning. Meta-analyses by Machts et al. (2016) and Südkamp et al. (2012) found that teachers exhibit relatively high accuracy in judging students' cognitive abilities and learning achievements. However, when it comes to motivational-affective characteristics, such as self-concept and interest, challenges arise, and teachers' accuracy tends to fluctuate (Spinath, 2005). Nevertheless, previous studies have predominantly focused on evaluating the accuracy of teachers in judging single—isolated—student characteristics, potentially overlooking the holistic nature of how teachers perceive students and make judgments by considering multiple learning-relevant characteristics (Kaiser et al., 2013).

To overcome this limitation, a novel line of research has emerged, focusing on exploring the accuracy of teachers in judging complex student profiles (Huber and Seidel, 2018; Südkamp et al., 2018; Schnitzler et al., 2020). Recognizing the interconnectedness of various student characteristics in a latent student profile, this new approach seeks to understand how teachers can effectively integrate and evaluate a range of characteristics simultaneously. Regarding teachers' judgment accuracy, preliminary evidence suggests that teachers tend to overestimate the consistency of student profiles and face challenges in identifying student profiles with conflicting information about cognitive and motivational-affective characteristics (e.g., a student with high cognitive ability but low self-concept; Huber and Seidel, 2018; Südkamp et al., 2018). To explain variations in teacher judgment accuracy when diagnosing student profiles, research has focused on teacher professionalization and expertise, indicated by teachers' professional experience (Seidel et al., 2020). To understand how experience can affect judgment in diagnosing student profiles, it is essential to delve into teachers' diagnostic reasoning to gain insight into the role of experience and its potential influence on the judgment accuracy of student profiles.

The present study builds on previous studies (Huber and Seidel, 2018; Südkamp et al., 2018; Schnitzler et al., 2020; Seidel et al., 2020) by employing an expert-novice paradigm to examine teachers' judgment accuracy in the context of diagnosing student engagement and underlying latent student profiles. The study focuses on five distinct student profiles, including three inconsistent profiles (overestimating, uninterested, and underestimating) and two consistent profiles (strong and struggling). By delving into teachers' reasoning as grounded in the framework of teacher professional vision (Seidel and Stürmer, 2014), this study establishes a new perspective on the differences between experienced and novice teachers when diagnosing student profiles.

1.1 Teachers' diagnosing of student learning characteristics

In the educational context, teachers' *diagnosing* is characterized by teachers' assessment of their students' diverse characteristics and learning needs (Artelt and Gräsel, 2009). Research focusing on teachers' diagnosing is mainly interested in three kinds of teacher *judgment accuracy*, which refers to their performance in accurately judging student characteristics: Firstly, research about teachers' task-related judgment accuracy, focuses on teachers' ability to judge the difficulty of tasks based on the collective performance of the class (McElvany et al., 2009). Secondly, research about teachers' person-specific judgment accuracy delves into teachers' ability to judge individual student behaviors, including mental disorders (Mathews et al., 2020) and learning difficulties in mathematics (Kilday et al., 2011). Thirdly, especially in recent years, there has been increasing research interest in teachers' person-related judgment accuracy, which includes teachers' judgment of various cognitive and motivational-affective characteristics of students. These include but are not limited to, subject-specific self-concept (Helm et al., 2018), achievement (Südkamp et al., 2012), and cognitive ability (Machts et al., 2016). On the one hand, research highlights the positive correlations between student characteristics, learning behaviors, and academic achievements (Wigfield and Eccles, 2000). On the other hand, research emphasizes how teachers' tailored instructional methods (e.g., level of support, feedback, or task choice) can positively influence these student characteristics (Schrader and Helmke, 1987; Corno, 2008; Urhahne and Wijnia, 2021). However, to optimally support student development, teachers need to accurately assess student characteristics (Urhahne and Wijnia, 2021). Research has shown that teachers vary in their accuracy in judging various student characteristics. They are generally more accurate at judging cognitive student characteristics in terms of academic achievement, with correlations between teacher judgments and actual student achievement ranging between $r = 0.20$ and $r = 0.90$ (median $r = 0.66$; Hoge and Coladarci, 1989; Machts et al., 2016). On the other hand, judging motivational-affective student characteristics, such as test anxiety and academic self-concept, are less accurate, with correlations ranging from $r = -0.39$ to $r = 0.82$ (median $r = 0.39$; Spinath, 2005). When considering this statistical synthesis of study results, it is important to note that the studies included in meta-analytic approaches vary widely in terms of methodological study characteristics (direct vs. indirect ratings, norm-referenced vs. peer-dependent ratings, measures of constructs). However, as Urhahne and Wijnia (2021) summarized in their synthesis of 40 years of research on teacher judgment, teacher judgments in areas other than student achievement often have relatively low levels of accuracy. Moreover, there is a significant gap in these studies as they primarily focus on single student characteristics in isolation and therefore, neglect the interconnected nature of student characteristics within students.

1.2 Diagnosing student profiles

Evidence suggests that teachers often perceive students holistically, interweaving different student characteristics when asked to judge specific aspects, such as student achievement or motivation (Südkamp et al., 2018). For example, Kaiser et al. (2013) observed that teachers' judgments are not limited to individual student characteristics, but are influenced by their perceptions of other student characteristics as well. Using structural equation modeling, the authors showed that teachers used students' achievement to make judgments about students' level of motivation. Evidence from variable-centered analyses shows that student characteristics are indeed significantly correlated (e.g., levels of academic achievement and prior knowledge; Schrader and Helmke, 2008). However, judging one characteristic based on another characteristic can result in a biased judgment (also referred to as halo effect; Fiedler et al., 2002), for example, when a student's cognitive and motivational-affective characteristics are not consistently high or low.

To explore the dynamics of student characteristics within individuals while simultaneously mapping the diversity of student characteristics among different groups, person-centered analyses gained increasing attention (Seidel, 2006; Linnenbrink-Garcia et al., 2012; Kosel et al., 2020). Person-centered analyses go beyond examining isolated student characteristics (i.e., variable-centered analyses) by integrating different student characteristics and describing their inherent structure within a person, such as a student (Lubke and Muthén, 2005). In education, person-centered approaches are used to identify different *student profiles* based on their unique combination of student characteristics. Research has uncovered a variety of student profiles with varying combinations of cognitive and motivational-affective student characteristics (Seidel, 2006; Linnenbrink-Garcia et al., 2012; Kosel et al., 2020). For instance, Kosel et al. (2020) analyzed data on about 10.000 German 9th-grade students' cognitive abilities, prior knowledge, self-concept, and interest in the two subjects of mathematics and language arts. Using latent profile analysis, they showed for both subjects that some groups of students have *consistent profiles* of cognitive and motivational-affective characteristics and can be categorized as either "strong students" or "struggling students," meaning they have consistently high or low values in student characteristics data. Other students exhibit *inconsistent profiles*, such as "underestimating students" (knowledgeable but lacking confidence in their self-concept of ability), "overestimating students" (less knowledgeable but highly confident in their self-concept of ability), or "uninterested students" (overall knowledgeable and confident but with limited interest in a subject area). Regarding the distribution of profiles, the underestimating student profile was prevailing in both subjects (around 35 percent of the students), with the second highest prevalence being observed for the struggling profile in mathematics (around 24 percent) and the overestimating profile in language arts (around 27 percent). The findings thus indicate that teachers in varying subjects are often confronted with students having inconsistent profiles of cognitive and motivational-affective characteristics.

Huber and Seidel (2018) as well as Südkamp et al. (2018) explored student profiles by comparing teacher and student perceptions regarding the interplay of cognitive and motivational-affective student characteristics. In both studies, the authors found that teachers' perceptions were dominated by homogeneous sets of average student characteristics. For example, Südkamp et al. (2018) found that teachers tend to rate their students consistently as either above average, average, or below average on cognitive and motivational-affective student characteristics; in contrast, students' ratings indicated a diverse and sometimes inconsistent interplay of student characteristics. Thus, teachers seem to struggle with decoupling different student characteristics but instead tend to assume consistency in student profiles—although, contrary to the authors' expectations, teachers' judgments were not more accurate for consistent compared to inconsistent student profiles.

1.3 The role of professional experience

The tendency toward assuming consistency between student characteristics can be ascribed to teachers' cognitive processes. Südkamp et al. (2018) acknowledge the role of heuristic information processing—an automatic, unconscious, and, thus, efficient processing of information (see Evans, 2008)—in teacher judgments. Heuristic information processing is generally favored under situational conditions, such as limited time or information to act on (Chaiken and Trope, 1999), which are common conditions of teaching situations. *Heuristics* are mental shortcuts that simplify cognitive inferences (Kahneman and Klein, 2009; Norman et al., 2017). They can result in biased judgment (e.g., halo effect; Fiedler et al., 2002) but can also be highly functional if based on professional knowledge and experience (e.g., Boshuizen et al., 2020).

Professional knowledge initially consists of the knowledge that novice teachers learn in the course of their studies, which is later elaborated and restructured into higher-order representations through professional experience (Boshuizen et al., 2020). One such knowledge representation is cognitive prototypes, which are representations of categories (e.g., "students") with typical attributes (e.g., student characteristics) or patterns of attributes (e.g., student profiles) that were abstracted from experience (Cantor and Mischel, 1977; Hörstermann et al., 2010; Papa, 2016). With increasing experience, teachers are exposed to a greater number and a greater variety of students, allowing them to refine their cognitive prototypes of typical student characteristics and student profiles (Boshuizen et al., 2020). Drawing on their elaborated professional knowledge, experienced teachers thus have superior prerequisites for accurately diagnosing student profiles. This assumption was supported in a study by Seidel et al. (2020), in which teachers were asked to assign students to consistent and inconsistent student profiles based on an authentic video vignette about the students' learning behavior. The results indicated a higher accuracy on the side of experienced teachers compared to novice teachers in judging student profiles. However, other existing studies report heterogeneous results regarding the influence of professional experience on judgment accuracy (Royal-Dawson and Baird, 2009; Ready and Wright, 2011); for instance, Ready and Wright (2011) asked teachers with different levels of experience to predict students' test scores and found lower correlations between predicted and actual scores for more experienced teachers. These studies emphasize that teachers' experience does not necessarily lead to higher judgment accuracy but other factors, for example, relating to diagnostic processes, are relevant to consider as well.

Some studies investigated cognitive processing in teachers' diagnosing. These studies have shown that experienced teachers with elaborated professional knowledge are better able to constantly monitor the responses and activities of all students in class, while at the same time being alert to those students and events that might require particular actions or adaptations during teaching (Clarridge and Berliner, 1991; Stahnke and Blömeke, 2021; Wolff et al., 2021; Kosel et al., 2023). Goodwin (1994) characterized this phenomenon as *professional vision*—a concept that was further elaborated by researchers, such as van Es and Sherin (2010) and Seidel and Stürmer (2014). Professional vision denotes the ability of teachers to effectively engage in cognitive and behavioral facets of classroom observation, which shapes their instructional practices and decision-making in educational contexts. Seidel and Stürmer (2014) distinguished two fundamental dimensions of professional vision: *noticing* student behavior by directing attention to relevant information; and *reasoning*, which is the cognitive interpretation of the collected information. Experienced teachers' elaborated knowledge drives their ability to notice relevant cues or factors that novices may miss (Clarridge and Berliner, 1991). Moreover, elaborated professional knowledge facilitates teachers' reasoning in terms of seamlessly integrating situational information with their professional knowledge (Wolff et al., 2021), which can lead to more nuanced and accurate judgments than novice teachers who had limited exposure to the intricacies of the profession. Thus, when diagnosing student profiles, teachers' reasoning underlying their final judgment is influenced by their professional knowledge and experience regarding student characteristics and typically occurring student profiles.

1.4 Teachers' diagnostic reasoning

Student learning characteristics and their integration into student profiles are not directly observable but represent latent constructs, which teachers diagnose through reasoning about noticed cues regarding the students' behavior (Back and Nestler, 2016). To underscore the crucial role of observable cues in shaping teachers' judgments, recent models of teacher judgment (Herppich et al., 2018; Loibl et al., 2020) referred to the lens model proposed by Brunswik (1955). As teachers observe and interpret a myriad of observable cues, they construct mental representations of students' latent characteristics as a basis for making informed judgments. For example, in a diagnostic situation where a teacher is judging a student's self-concept, the teacher identifies observable cues—such as behaviors (e.g., lack of eye contact) and interactions (e.g., avoidance of group activities)—that may indicate the student's self-concept. The teacher correlates these various cues as an indicator of the student's self-concept, thereby validating the cues with each other and making a probabilistic yet informed judgment about the student's self-concept as a latent construct. Some cues can be characterized as *surface cues* (Brunswik, 1955; Loibl et al., 2020) because they are directly observable. As indicated by prior research on classroom management, such surface cues—for example, overt signs of disinterest (e.g., playing with a pen) or disruptive behavior (e.g., talking to other students or throwing around things)—are easily perceived by teachers (Stürmer et al., 2017). In contrast, *deep cues* require making some interpretation from direct observations. For example, remaining quiet in the classroom can be an indicator of low self-concept but also low motivation (Seidel et al., 2016). Such deep cues are often challenging for teachers to evaluate (Kaiser et al., 2013; Südkamp et al., 2018).

Although there is sparse research on experienced and novice teachers' noticing and reasoning about deep cues, Jacobs et al. (2010) explored how teachers with varying levels of experience notice and reason about students' mathematical understanding in on-the-fly assessments. Even when being explicitly prompted to focus on student understanding, novice teachers failed to point to specific evidence; by contrast, the large majority of experienced teachers was able to provide evidence regarding students' level of understanding.

Building on the finding of Seidel et al. (2020) that experienced teachers were partially more accurate than novice teachers at diagnosing student profiles, Schnitzler et al. (2020) further explored the reasoning of novice teachers in terms of cues regarding student behavior (e.g., hand-raisings). Using epistemic network analyses (ENA; Shaffer, 2017)—a method that is designed to explore epistemic processes, such as teachers' reasoning (e.g., Bauer et al., 2020; Farrell et al., 2022)—Schnitzler et al. (2020) explored the reasoning of novice teachers from the sample of Seidel et al. (2020) regarding different indicators for student engagement (i.e., behavioral, cognitive, emotional, knowledge-related, and confidence-related indicators; see Rimm-Kaufman et al., 2015) across different student profiles. The findings indicated that generally, the novice teachers mainly focused on the intensity of student engagement in terms of well-observable behavioral cues (e.g., students' hand-raising), which can be considered surface cues. In addition, novice teachers sometimes referred to the content of students' engagement (e.g., students' quality of verbal contributions) in their reasoning, which might be considered as ranging between surface and deep cues (see Jacobs et al., 2010). Deep cues that were more inferential—for example, cues regarding students' cognitive (e.g., inattention) or emotional engagement (e.g., interest), as well as students' confidence (e.g., certainty in providing answers)—were hardly included in novices' reasoning. In terms of judgment accuracy, the study found that novice teachers with comparably high accuracy in judging student profiles focused not exclusively on behavioral cues and related cues in ways that differentiated between student profiles with similar patterns of cues. For example, to identify the underestimating student profile, novice teachers with high accuracy focused on behavioral cues indicating the intensity of engagement (e.g., raising hands) and additionally considered the content of students' engagement (e.g., students' quality of verbal contributions)—which facilitated distinguishing the underestimating student profile, for example, from the struggling student profile. By contrast, novice teachers with low judgment accuracy seemed to miss or misinterpret those cues that facilitated successful differentiation between similar student profiles.

However, Schnitzler et al. (2020) focused on the analysis of novice teachers' diagnostic reasoning and, therefore, did not include the experienced teachers from the study of Seidel et al. (2020) in their investigations. Thus, experienced teachers' reasoning when diagnosing student profiles remained to be explored, to better understand how experienced teachers might differ from novice teachers in their reasoning when diagnosing latent student characteristic profiles based on student cues.

2 The present study

The present study investigates differences between novice and experienced teachers' judgment accuracy and their diagnostic reasoning when asked to diagnose consistent and inconsistent student profiles (Seidel, 2006; Kosel et al., 2020). In doing so, we included the novice teachers investigated by Seidel et al. (2020) and Schnitzler et al. (2020) and the experienced teachers from Seidel et al. (2020), while adding additional experienced teachers to the sample in order to achieve comparable group sizes in the two subsamples. Because of the increased subsample of experienced teachers, we decided to investigate the replicability of the findings regarding the difference in novice and experienced teachers' judgment accuracy in diagnosing student profiles. In our study, teachers' judgment accuracy refers to their performance in accurately assigning five student characteristic profiles (i.e., strong, struggling, overestimating, uninterested, and underestimating students) to five videotaped students, whose characteristic profiles were empirically determined in advance.

However, the main attention of our research was set on exploring the reasoning of experienced teachers in comparison to the reasoning of novice teachers when diagnosing student profiles because, to our knowledge, this question has not been explored in research thus far. In our study, teachers' diagnostic reasoning is characterized by student engagement cues coded in teachers' written explanations of their diagnostic judgments. We explore novice and experienced teachers' diagnostic reasoning about cues regarding student engagement using the method of ENA (Shaffer, 2017), which is a powerful tool to explore the reasoning about cues regarding student engagement when diagnosing student profiles. In doing so, the study aimed to gain insights into how professional experience influences teachers' diagnosing of student profiles, which might offer valuable implications for supporting educational practice and designing targeted training for teacher education.

Teachers' judgment accuracy and diagnostic reasoning might differ systematically across varying student characteristics profiles, which may result, for example, in a higher or lower overall judgment accuracy across all student profiles. In addition, investigating novice and experienced teachers' diagnosing of individual student profiles (i.e., strong, struggling, overestimating, uninterested, and underestimating students) can indicate which student profiles are most challenging to diagnose and what might be reasons for performance differences between novice and experienced teachers' diagnosing. The two research questions addressed in our research are:

RQ1: Are there systematic differences between novice and experienced teachers (a) in their overall judgment accuracy across student profiles and (b) in their judgment accuracy regarding individual student profiles?

Seidel et al. (2020) report evidence with a smaller sample of experienced teachers suggesting that experienced teachers tend to have an advantage over novices when diagnosing student profiles. Over time, experienced teachers have encountered a wide variety of cues and common cue patterns (Carter et al., 1988; Boshuizen et al., 2020) and have thereby developed a fine-grained professional vision (Gegenfurtner et al., 2022). Therefore, we hypothesize that, compared to novice teachers, experienced teachers show (a) a higher overall judgment accuracy when diagnosing student profiles and (b) a higher judgment accuracy regarding individual student profiles.

RQ2: What combination of cues do experienced teachers use in their reasoning when diagnosing student profiles and is there a systematic difference compared to novice teachers in (a) the overall reasoning across different student profiles and (b) the reasoning regarding individual student profiles?

Also for this exploratory research question, we assumed that experienced teachers' professional vision facilitates their diagnostic reasoning, possibly resulting in a higher variety and a higher number of cues—including deep cues—compared to novice teachers, who were found to refer primarily to surface cues regarding student engagement when diagnosing student profiles (Schnitzler et al., 2020).

3 Methods

3.1 Participants

The sample consisted of $N = 43$ participants and included $n = 24$ novice teachers (female = 55%) enrolled in a university bachelor's degree program to become secondary mathematics teachers and $n = 19$ in-service mathematics teachers (female = 64%) with a mean teaching experience of $M = 10.92$ years ($SD = 9.11$, *range* = 1.5–25.0 years). The subsample of novice teachers was the same as explored in Schnitzler et al. (2020) and Seidel et al. (2020); the subsample of experienced teachers was extended by 11 participants compared to the study of Seidel et al. (2020).

3.2 Procedure and materials

The present study was conducted under the Ethical Principles of Psychologists and the 2017 Code of Conduct of the American Psychological Association (American Psychological Association, 2017). Participants were assured that their data would be used following privacy policies and analyzed for scientific purposes only. Participants provided informed consent before participation.

The experiment was conducted in the laboratory, with only one participant at a time. Participants were seated in front of a computer and the experiment was conducted in the experimental computer environment Enterprise Feedback Suite Survey 22.2 (Tivian, 2022). First, participants were given a short theoretical introduction to each of the student characteristics under study: cognitive ability, interest, prior knowledge, and self-concept as well as their within-person interplay in strong, struggling, overestimating, underestimating, and uninterested student profiles.

After the introduction, participants watched a short video (2:30 min) of a lesson to familiarize themselves with the lesson topic and the classroom environment. Next, participants were instructed to carefully observe an 11-min video stimulus and diagnose student profiles afterward (see Figure 1). The 11-min video showed an eighth-grade geometry introductory lesson from a German high school. The video clip was recorded in the context of a previous video study on teacher-student interactions in classrooms and showed natural student behavior as it was videotaped in a real classroom situation (Seidel et al., 2016). Each target student was labeled with a random letter (B, E, K, P, T) throughout the video clip.

The labeled students in the video represented the strong, struggling, uninterested, overestimating, and underestimating student profiles. The student profiles were empirically determined using latent clustering in prior research by Seidel (2006) as well as Huber and Seidel (2018). This person-centered and latent clustering-based research aimed to explore homogenous subgroups of students, each distinctly characterized by a unique combination of cognitive characteristics (such as prior knowledge) and motivational-affective characteristics (e.g., self-concept). For instance, a specific student profile is assigned to students who demonstrate both high self-concept and substantial prior knowledge, categorizing them as strong students. This group is statistically differentiated from others, notably those with high self-concept yet limited prior knowledge, who are classified as overestimating students. However, it is important to recognize that the accuracy of these student profiles is dependent on the precision and robustness of the underlying research methods and instruments used and that the student profiles studied cannot be treated as objective truths. Latent clustering assigns students to student profiles based on the probability of them belonging to a specific homogenous subgroup including assignment errors (Spurk et al., 2020).

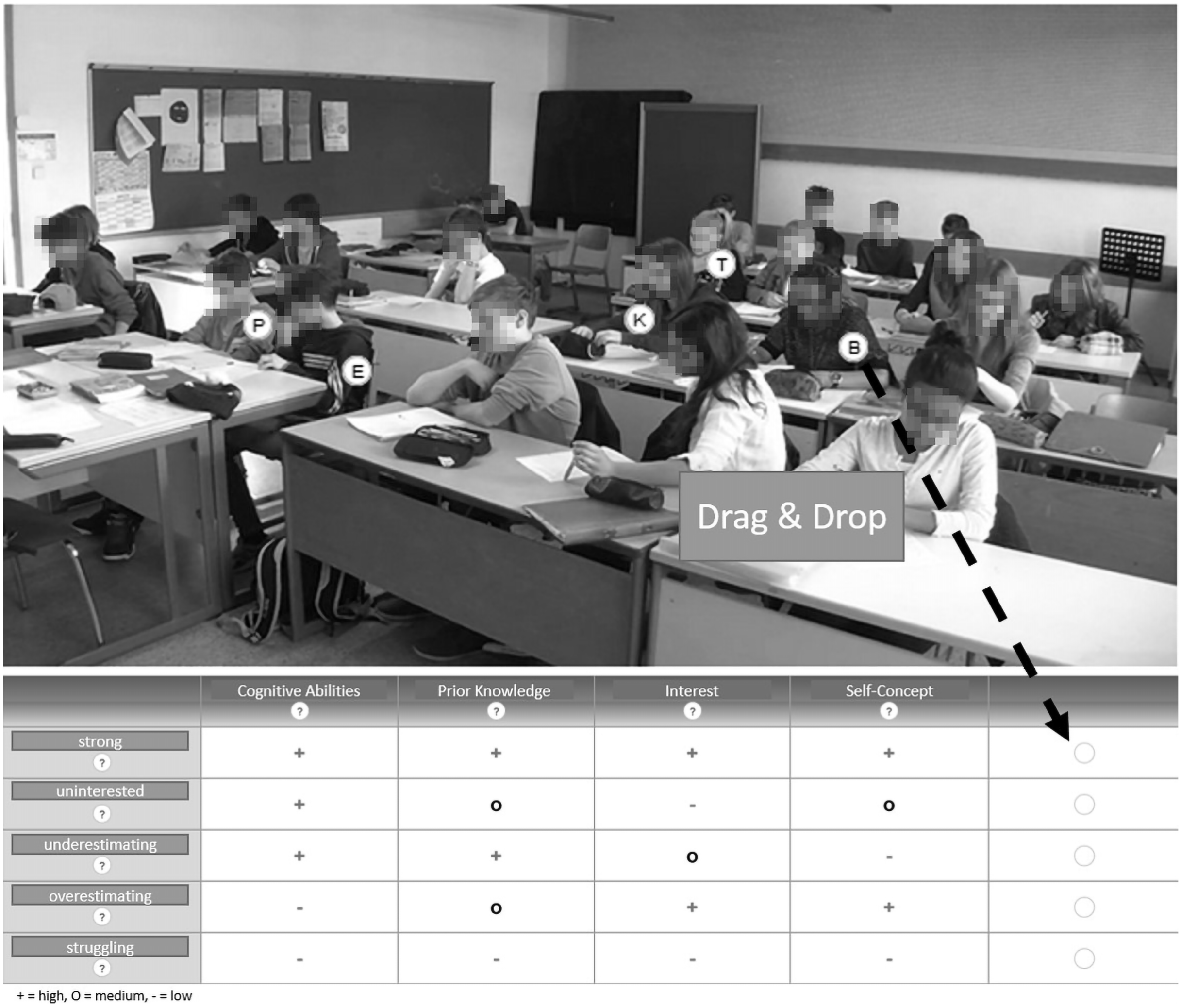

FIGURE 1
Example screenshot of the video clip and final drag & drop judgment task after observing the video clip with the labeled students.

3.3 Measures

3.3.1 Judgment accuracy

The correct judgment of a student was based on its match to the corresponding student profile. To perform the judgment after observing the video clip with the labeled students (the letters were unconnected to the profiles), participants were prompted to drag and drop the letters into a table, corresponding to their judgment of the student profile (see Figure 1). In case they were uncertain, they were also able to assign an additional, alternative profile. For each student profile, participants were assigned an accuracy score: A score of 0 represented an incorrect diagnosis. If a teacher first assigned an incorrect profile but stated the correct profile in their alternative choice, they received 0.5 points. Teachers received a score of 1 for a correct diagnosis. Overall, participants' cumulative scores could range from a score of 0 (no correct judgments) to a score of 5 (all judgments correct).

3.3.2 Reasoning

To analyze the reasoning of experienced and novice teachers, we coded their open-ended responses to a question that asked the participants about the diagnostically relevant cues they had observed and used to judge student profiles. This question was asked for each of the five target student profiles separately. To code the written responses, we used a fine-grained coding scheme developed by Schnitzler et al. (2020; building on research on student engagement, e.g., Rimm-Kaufman et al., 2015), consisting of five categories of codes: (1) knowledge (e.g., high quality of verbal contributions, problems with comprehension), (2) behavioral engagement (e.g., active participation, frequent hand-raising), (3) cognitive (e.g., student is attentive), (4) emotional engagement (e.g., student is interested or bored), and (5) student confidence (student is certain and uncertain). Overall, the coding scheme included these 5 categories and 26 corresponding sub-codes, as shown in Table 1. Two researchers coded the open-ended responses inductively following the coding scheme and reached a sufficiently high interrater agreement for the sample of novice teachers (Cohen's $\kappa = 0.93$) and for the sample of experienced teachers (Cohen's $\kappa = 0.89$).

3.4 Data analysis

3.4.1 RQ1: ANOVA of teachers' judgment accuracy

To examine the judgment accuracy of experienced and novice teachers, the distribution of their overall judgment accuracy scores

TABLE 1 Coding scheme for student behavioral cues.

Category	Codes
Knowledge	High quality of verbal contributions
	Low quality of verbal contributions
	Understanding of topic
	Problems with understanding
	Helps classmates
	Receives help
Behavioral	Active participation
	No participation
	Frequent hand-raisings
	No or only few hand-raisings
	Fast working
	Slow working
	Following gaze
	Digressive gaze
	Interacts with classmates
	Does not interact with classmates
	Inconspicuous
	Otherwise involved
Cognitive	Attentive
	Inattentive
	Concentrated
Emotional	Interested
	Uninterested
	Bored
Confidence	Certain
	Uncertain

Adapted from Schnitzler et al. (2020).

was examined descriptively. Second, a 5×2 factorial ANOVA was used to examine differences in judgment accuracy across five student profiles (factor 1) and different levels of professional experience (factor 2) (RQ1a). Then a *post hoc* analysis was conducted using the Benjamini-Hochberg procedure to control for multiple comparisons. The Benjamini-Hochberg procedure is a method used to control the false discovery rate when conducting multiple comparisons (Agresti, 2007). The false discovery rate is the expected proportion of false positives among all significant results. Unlike the traditional Bonferroni correction, which controls the familywise error rate and can be overly conservative, the Benjamini-Hochberg method provides a balance between reducing the risk of Type I errors (false positives) and maintaining statistical power (Agresti, 2007). In our analysis, we used the Benjamini-Hochberg procedure to adjust the p-values obtained from pairwise t-tests comparing the judgment scores for each profile between novice and experienced teachers (RQ1b). We performed these tests to determine if there were significant differences in judgment scores for each profile based on the teacher's experience level. Statistical analyses were performed using Python and the Pandas library (McKinney, 2010).

Upon conducting diagnostic checks for the ANOVA, we found that homogeneity of variances was maintained, as affirmed by Levene's test ($p > 0.05$). No outliers were identified in the judgment scores, with the definition for an outlier being $z > 3$ (Grubbs, 1969). In addition, we verified the assumption of independence of observations. This confirms that each data point in our data set is independent of the others, ensuring the validity of the conclusions drawn from our analysis. However, the Shapiro–Wilk test showed a non-normal distribution of residuals, violating the normality assumption and implying potential skewness or heavy-tailed residuals. Despite this violation, two-factor ANOVAs' robustness against such a deviation allowed us to remain within the parametric analysis design (Edwards, 1993).

3.4.2 RQ2: ENA of teachers' reasoning

To investigate novice and experienced teachers' diagnostic reasoning, we used the ENA method (Shaffer, 2017) to explore the cues that were coded in the participants' written responses. The general data processing of the ENA and the decisions to be made for the analysis are explained in the following (for an extended tutorial on ENA see Shaffer et al., 2016).

As a basis for the network model, the ENA algorithm accumulates co-occurrences of elements in coded data (e.g., observable cues coded in written responses). For doing so, it is required to specify how and for which units ENA should accumulate co-occurrences of codes: Our data consisted of participants' reasoning regarding individual student profiles, recorded in one short written response per student profile. Because of (a) the shortness of the responses and (b) the task to reason about a diagnostic judgment, we assumed that each written response intended to create a coherent overall meaning and, thus, that all codes within a written response should be considered as interconnected; thus, we decided to set the "window" for accumulating the data (referred to as "stanza") to the setting of "whole conversation," meaning that co-occurrences of codes in our data were initially accumulated for each written response (alternatively, ENA allows, for example, to use a "moving window" setting to account for temporality in the data). We used a weighted summation of the codes (instead of a binary summation), accounting for varying frequencies of codes (i.e., cues) in the data that we considered as indicating how important participants considered different cues. Because the written responses were interdependent for each participant, who further belonged to the group of either novice or experienced teachers, we set the unit for analysis to "participant" and then further accumulated the participants per subsample group (i.e., novice and experienced teachers).

The ENA algorithm accumulates the coded data for each stanza (e.g., written response per student profile) and each unit of analysis (e.g., participants grouped into subsamples of novice and experienced teachers) into cumulative adjacency matrices that are further converted into adjacency vectors in a high-dimensional space. The adjacency vectors are then spherically normalized to control for differences in the overall amount of data per unit of analysis (e.g., length of written responses per participant), thereby transforming frequencies of co-occurrences to relative frequencies of co-occurrences. To facilitate interpretation and visualization of the normalized adjacency vectors, ENA performs a singular value decomposition: It rotates the original high-dimensional space such that the rotated space provides a reduced number of dimensions that account for the maximum variance in the data. The resulting multidimensional network model can then be depicted as two-dimensional network graphs. Per default, the graphs align the dimension with the highest amount of explained variance with the x-axis and the dimension with the second highest amount of explained variance with the *y*-axis. However, instead of using this default setting, we used the option of "means rotation," which is recommended for comparing differences between two groups (e.g., novice and experienced teachers): The means rotation identifies the dimension with the highest systematic variance in explaining the differences between two selected groups and aligns this dimension with the *x*-axis of the network graph.

For every unit (e.g., participants), the ENA algorithm identifies at which point the corresponding normalized adjacency vector is located. For grouped units (e.g., participants grouped as novice and experienced teachers), the point representing the overall group can be considered a group mean. When using means rotation, the group means or the selected two groups are aligned with the *x*-axis. To facilitate interpretation, we consistently positioned novice teachers on the left and experienced teachers on the right for all network graphs.

In the two-dimensional network graphs, the coded cues in teachers' responses are represented by gray nodes, with the size of the gray nodes referring to the relative frequency of their occurrences. The location of the nodes is relative to the normalized vectors for each unit: In our network graphs, this means, for example, that nodes (i.e., cues in teachers' reasoning) that are close to one of the group means (e.g., cues positioned rather left in the network space, toward the novice teachers' group mean) are more typically associated with the that group than with the other group whose group mean is more distant (e.g., experienced teachers on the right).

The colored edges in the network graphs refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations (i.e., the relative frequency of co-occurrences). Weak relations were not shown in our network graphs to facilitate the interpretability of the networks (the minimum edge weight was set to 0.06). For group comparisons, ENA creates a set of three related network graphs respectively: In our analysis, one network graph depicts the novice teachers' reasoning, one network graph depicts the experienced teachers' reasoning, and a comparison graph depicts only the differences between the novice and experienced teachers' reasoning.

To explore (RQ2a) novice and experienced teachers' reasoning across different student profiles, we initially compared the network graphs as specified above, accumulating co-occurrences of cues coded in the written responses per participant and then per group of novice and experienced teachers. To explore (RQ2b) novice and experienced teachers' reasoning about each student profile in more detail, we filtered the written responses that addressed the individual student profiles and then performed the same analysis for each student profile.

In addition to performing a qualitative interpretation of the network graphs, we statistically tested group differences between novice and experienced teachers' reasoning, using one independent-samples *t*-test for each comparison. For RQ2a, the alpha level was set to $\alpha = 0.05$. For RQ2b, we controlled the false discovery rate when conducting multiple comparisons by using Bonferroni-adjusted alpha levels of $\alpha = 0.01$ ($\alpha = 0.05/5$). We created the network graphs with the ENA online tool.[1]

1 https://www.epistemicnetwork.org/

4 Results

4.1 RQ1: Teachers' judgment accuracy

4.1.1 RQ1a: Teachers' overall judgment accuracy

The primary goal of our first research question is to identify potential systematic differences between novice and experienced teachers with regard to the accuracy of their judgments. Specifically, we aim to (a) assess their overall accuracy in assessing different student profiles, and (b) examine the accuracy of their judgments for each individual student profile. Descriptively, we found that experienced teachers generally had a higher overall judgment score ($M = 3.47$; $SD = 1.26$), compared to novice teachers ($M = 2.42$; $SD = 1.62$). However, the standard deviations indicate substantial variability within both groups. Figure 2 presents a boxplot visualization of the overall judgment accuracy, highlighting a higher median score for experienced teachers. Additionally, the boxplot suggests a slightly larger range of scores for novice teachers, implying greater variability in their overall judgment scores.

4.1.2 RQ1b: Teachers' judgment regarding individual student profiles

In a more granular examination of judgment accuracy, we differentiated the analysis by individual student profiles (Figure 3). We observed systematic variations between experienced and novice teachers in their judgment (sorted from best to worst judgment scores): When judging the underestimating profile, experienced teachers had a mean score of 0.76 ($SD = 0.39$), whereas novice teachers had a mean score of 0.50 ($SD = 0.44$). In the uninterested profile, experienced teachers had a mean judgment score of 0.76 ($SD = 0.42$) in contrast to the novice teachers' mean score of 0.65 ($SD = 0.48$). For the struggling profile, the mean judgment score was 0.66 ($SD = 0.44$) for experienced teachers and 0.52 ($SD = 0.48$) for novice teachers. For the overestimating profile, experienced teachers had a mean judgment score of 0.58 ($SD = 0.42$), while novice teachers had a mean score of 0.29 ($SD = 0.44$). In judging the strong profile, experienced teachers demonstrated a mean score of 0.61 ($SD = 0.43$) compared to novice teachers' mean score of 0.54 ($SD = 0.46$).

In sum, it appears that both novice and experienced teachers consistently rate the uninterested and underestimating student profiles with the highest mean scores. However, when it comes to assessing the strong and overestimating profiles, experienced teachers exhibit superior judgment accuracy. In the next step, we analyze if these systematic variations are statistically significant.

A 5×2 factorial ANOVA (see Table 2) was performed to probe the differences in judgment accuracy, with the five distinct student profiles and varying levels of professional experience serving as the two factors under consideration. The main effect of student profile type was not significant ($F(4, 90) = 0.89$, $p = 0.47$, $\eta^2 = 0.04$), indicating that there was no significant difference in judgment scores across student profiles when teacher experience was not taken into account. However, the main effect of teacher experience level was significant ($F(1, 90) = 3.93$, $p = 0.05$, $\eta^2 = 0.04$), indicating a significant difference in judgment scores between novice and experienced teachers. The interaction effect between student profile type and teacher experience was not significant, $F(4, 90) = 0.94$, $p = 0.45$, $\eta^2 = 0.01$, indicating that the effect of student profile type on judgment scores did not differ significantly between novice and experienced teachers.

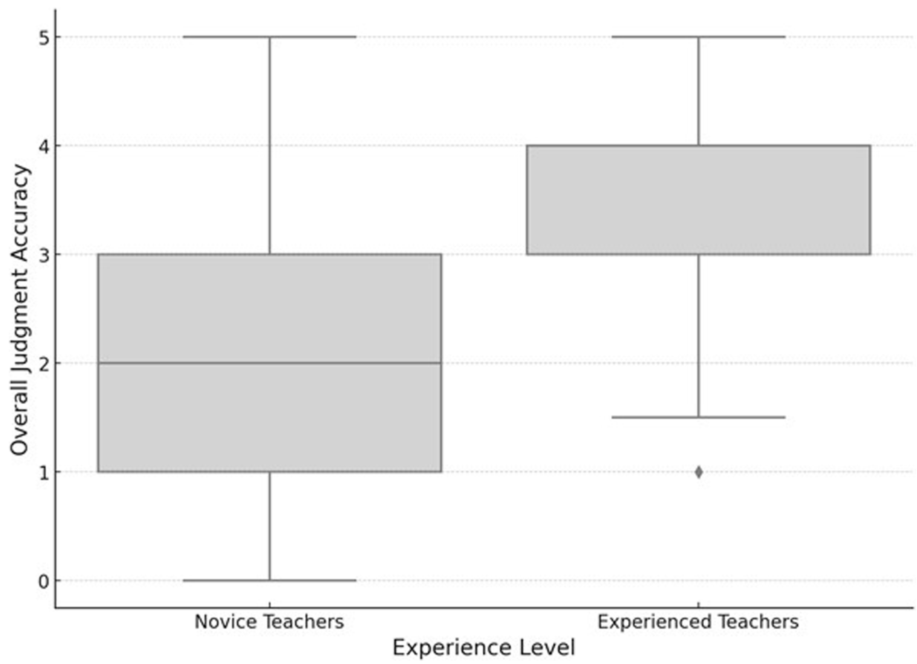

FIGURE 2
Overall judgment score across experience levels.

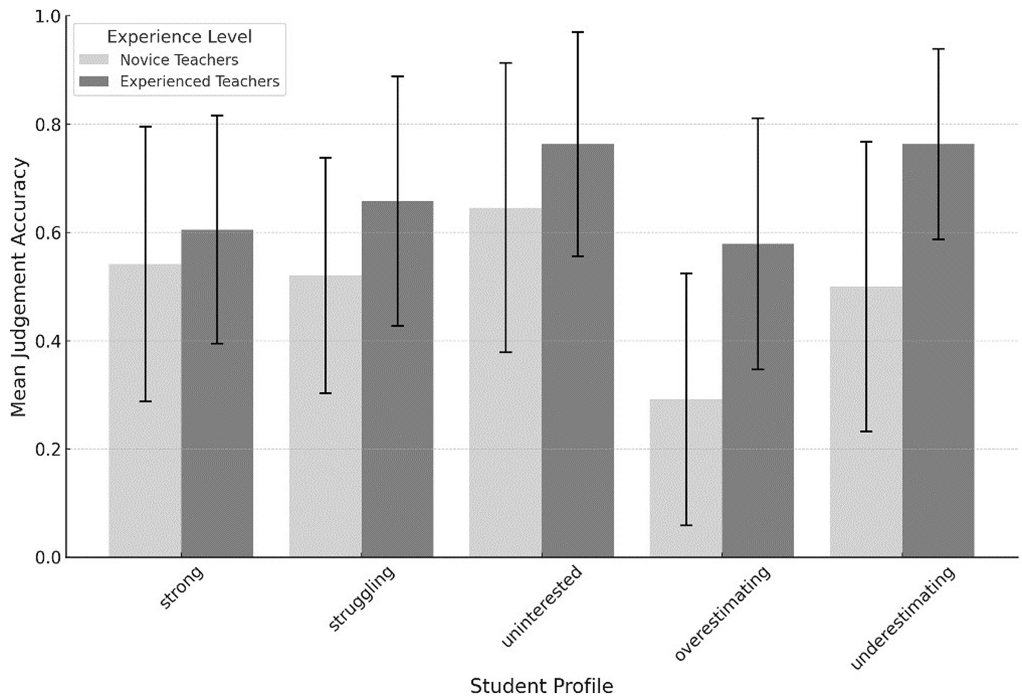

FIGURE 3
Mean judgment accuracy is separated for each student profile across experience levels.

Following the ANOVA, we conducted a *post hoc* analysis using multiple t-tests to compare the judgment score of novice and experienced teachers for each student profile. To adjust for the increased risk of Type I error associated with multiple comparisons, we applied the Benjamini-Hochberg correction procedure. We found that all adjusted *p*-values exceeded the conventional significance level of 0.05. This suggests that, when accounting for the multiplicity of tests performed, there were no statistically significant differences in the judgment scores of novice and experienced teachers within the different student profiles.

TABLE 2 5×2 factorial ANOVA: differences in judgment accuracy.

Source of variation	SS	df	MS	F	p	η^2
Student profile	0.17	4	0.04	2.26	0.47	0.04
Experience level	0.16	1	0.16	3.93	0.05	0.04
Student profile x Experience level	0.16	4	0.04	0.94	0.45	0.01
Residual	17.36	90	0.19			

TABLE 3 The 15 most frequently utilized student cues, sorted by category and separated by experience level.

Category	Cue	ET (%)	NT (%)	ET (freq.)	NT (freq.)
Knowledge	High-quality contributions	36%	27%	35	32
	Low-quality contributions	35%	25%	34	30
	Understand the topic	23%	7%	22	9
	Problems to understand the topic	17%	6%	17	8
Behavioral	A lot of hand-raisings	32%	25%	31	30
	No / few hand-raisings	27%	29%	30	34
Cognitive	Attentive	34%	20%	33	24
	Inattentive	29%	11%	28	14
Emotional	Interested	24%	11%	23	13
	Uninterested	15%	4%	15	5
Confidence	Certain	43%	29%	41	34
	Uncertain	30%	13%	29	16

ET, Experienced Teachers; NT, Novice Teachers.

4.2 RQ2: Teachers' reasoning

4.2.1 RQ2a: Teachers' reasoning across different student profiles

In order for tackle our second research question, we analyzed the coded open-ended questions. The responses provide insights into the specific student cues that teachers relied on when deducing underlying student profiles based on their observations. Table 3 displays the 15 most frequently stated behavioral cues, separated by experience level. On average, experienced teachers indicated 5.32 cues, and novice teachers 2.52 cues. The overall frequencies of cues and the frequencies of individual cues suggest that, compared to novice teachers, experienced teachers generally consider more and also a greater variety of cues. This finding is further elaborated in the following, integrating the descriptive results with the interpretation of the epistemic networks of novice and experienced teachers' diagnostic reasoning.

Using ENA, we can examine not only the frequency (i.e., occurrences) of individual cues, represented by the size of the gray nodes, but additionally the strength of relations (i.e., co-occurrences) of cues, which is represented by the thickness of the colored edges. Cues positioned toward the left, are more typically associated with novice teachers and cues positioned toward the right are more typically associated with experienced teachers. As described by Schnitzler et al. (2020), novice teachers primarily focus on well-observable behavioral cues (i.e., surface cues; e.g., a lot of hand-raising, digressive gaze) and additionally include some cues that refer to students' knowledge and comprehension of the topic (see Figure 4A). Looking at the relations of cues, novice teachers typically seem to combine these two types of cues (e.g., a lot of hand-raising with high-quality contributions; few hand-raising with low-quality contributions).

By comparison, experienced teachers' reasoning (see Figure 4C) across all student profiles indicates that experienced teachers consider a broad variety of student engagement cues when diagnosing student profiles, including well-observable behavioral cues (i.e., surface cues; e.g., a lot of hand-raising) but also motivational-affective cues that are partially rather latent and require some degree of inference (i.e., deep cues; e.g., uncertain). In addition, these various cues show to be well interrelated, which suggests that experienced teachers use a variety of cues in their reasoning and do so across different student profiles.

The difference between novice and experienced teachers' reasoning is further highlighted in the comparison graph (see Figure 4B), which shows a subtraction of the experienced and the novice teachers' reasoning networks: The comparison graph further highlights the observation that, overall, novice teachers related fewer and less varying cues compared to experienced teachers who related a broad variety of cues in their reasoning. This observation is supported by the frequencies of individual cues included by novice and experienced teachers in their reasoning (see Table 3).

The difference between novice teachers (position of the mean on the x-axis: $M = -0.23$, $SD = 0.10$) and experienced teachers (position of the mean on the x-axis: $M = 0.29$, $SD = 0.09$) in their reasoning across all five student profiles was statistically significant, $t(42.30) = -19.14$, $p < 0.01$, Cohen's $d = 5.68$.

Thus, the findings indicate that there are substantial differences in experienced and novice teachers' reasoning when diagnosing student profiles.

4.2.2 RQ2b: Teachers' reasoning about individual student profiles

The differences between novice and experienced teachers regarding their utilization of cues and relations drawn between cues can be further differentiated per student profile. Specific differences in novice and experienced teachers' reasoning when diagnosing the individual student profiles are illustrated in the following.

Strong Student. When diagnosing the strong student, novice teachers (see Figure 5A) focused especially on behavioral cues (i.e., surface cues), such as the student's frequent hand-raising. Novice teachers associated this behavior with the student's active participation and occasional signs of boredom, as well as the student's high quality of contributions (i.e., cue about the student's knowledge).

As indicated by the network of experienced teachers' reasoning (see Figure 5C) and the comparison graph (see Figure 5B), experienced teachers considered and related various behavioral and motivational-affective cues: These cues included cues that are not directly observable

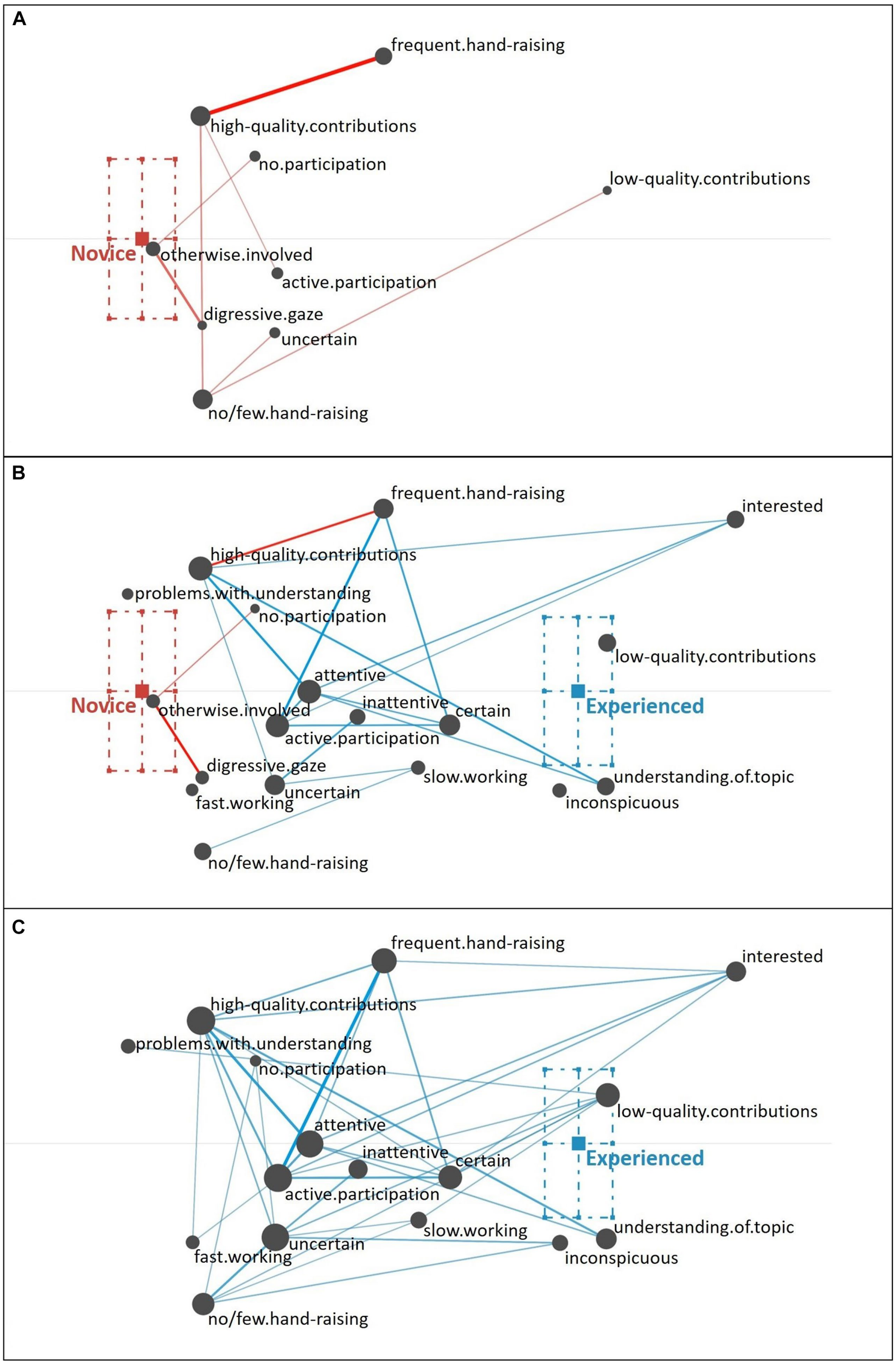

FIGURE 4
Epistemic network of teachers' reasoning across the five different student profiles from **(A)** novice teachers and **(C)** experienced teachers, with the **(B)** comparison network showing only the differences between novice and experienced teachers' reasoning across all five student profiles. Gray nodes correspond to cues, with node size referring to the relative frequency of their occurrence; colored edges refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations.

but involved some degree of inference (i.e., deep cues) on the side of the teacher, such as the student being interested and certain; however, the teachers related these cues to directly observable behavioral cues (e.g., a lot of hand-raising) as well as cues about the student's knowledge (e.g., high quality of contributions, understanding of the topic).

The difference between novice teachers' reasoning (position of the mean on the *x*-axis: $M = -0.09$, $SD = 0.12$) and experienced teachers' reasoning (position of the mean on the *x*-axis: $M = 0.49$, $SD = 0.18$) regarding the strong student profile was statistically significant, $t(30.26) = -11.72$, $p < 0.01$, Cohen's $d = 3.77$.

Struggling Student. Novice teachers characterized the struggling student (see Figure 6A) primarily based on the observation that the student exhibited hardly any hand-raising in combination with a low quality of their contributions and indications of uncertainty. Some novice teachers additionally pointed to a lack of participation and the student showing problems with understanding the topic, which is a combination of behavioral and knowledge-related cues as well. Interestingly, few novice teachers emphasized the high quality of the student's contributions, indicating a misinterpretation of the cues, which might have resulted in an inaccurate judgment of the student profile (see Schnitzler et al., 2020).

This misinterpretation was not shown by experienced teachers (see Figure 6C). Other cues discussed by the novice teachers were also considered by experienced teachers, who additionally included further behavioral cues (e.g., digressive gaze, slow working style; i.e., surface cues; see also Figure 6B for the direct comparison of novice and experienced teachers). Interestingly, besides the cues that might easily be recognized as potentially problematic, experienced teachers also pointed to the student being quiet and inconspicuous as well as the student being inattentive.

The difference between novice teachers' reasoning (position of the mean on the *x*-axis: $M = -0.11$, $SD = 0.11$) and experienced teachers' reasoning (position of the mean on the *x*-axis: $M = 0.29$, $SD = 0.11$) regarding the struggling student profile was statistically significant, $t(39.28) = -11.71$, $p < 0.01$, Cohen's $d = 3.61$.

Uninterested Student. Novice teachers described the uninterested student (see Figure 7A) as showing a digressive gaze in relation to being otherwise involved and not participating. Some novice teachers pointed out the student's slow working style. In addition to these behavioral (i.e., surface) cues, some novice teachers recognized the student as inattentive, showing some initial capacity to notice some more inferential (i.e., deep) cues.

In comparison (see Figure 7B), the experienced teachers rather pointed to additional behavioral cues (e.g., no or few hand-raising) and also focused on more inferential motivational-affective cues (i.e., deep cues), such as the student being inattentive and uncertain (see Figure 7C).

The difference between novice teachers' reasoning (position of the mean on the *x*-axis: $M = -0.26$, $SD = 0.24$) and experienced teachers' reasoning (position of the mean on the *x*-axis: $M = 0.18$, $SD = 0.08$) regarding the uninterested student profile was statistically significant, $t(31.06) = -8.55$, $p < 0.01$, Cohen's $d = 2.33$.

Overestimating Student. The cues used by novice teachers to characterize the overestimating student (see Figure 8A) comprise of frequent hand-raising (behavioral cue), oftentimes combined with pointing to a high quality of contributions (knowledge-related cue) and sometimes with the student's certainty and active participation in the lesson. Some novice teachers validated this impression with the observation that the student provides help or is asked for help by a second student (i.e., their seatmate), whereas few novice teachers interpreted the student talking to their seatmate differently, as seeking and receiving help. Overall, the cues involved in novice teachers' reasoning are not specific to the overestimating profile but also applicable to the strong profile, which explains why many novice teachers diagnosed the overestimating student as a strong student (see Schnitzler et al., 2020).

The experienced teachers validated the behavioral (i.e., surface cues) cues of frequent hand-raising and active participation with further motivational-affective cues (i.e., deep cues) besides certainty, namely the attentiveness and interest displayed by the student (see Figure 8C). In contrast to the novice teachers (see Figure 8B), experienced teachers also did not misinterpret the quality of the student's contribution as high but considered the quality of the student's contribution as low. They also regarded the interaction of the student with their seatmate as seeking and receiving help. The experienced teachers' reasoning was additionally backed up with further behavioral cues (i.e., slow working style) and knowledge-related cues (i.e., the student's problems with understanding the topic), which illustrated a realistic overall assessment of the overestimating student's skills.

The difference between novice teachers' reasoning (position of the mean on the *x*-axis: $M = -0.18$, $SD = 0.20$) and experienced teachers' reasoning (position of the mean on the *x*-axis: $M = 0.40$, $SD = 0.15$) regarding the overestimating student profile was statistically significant, $t(39.78) = 10.71$, $p < 0.01$, Cohen's $d = 3.24$.

Underestimating Student. When diagnosing the underestimating student, novice teachers again primarily focused on the behavioral cue of hand-raising (no or few hand-raising; i.e., surface cues) and tended to relate it to few additional cues out of three clusters (see Figure 9A): further behavioral cues (fast working style, active participation), knowledge-related cues (high quality of contributions, understanding of the topic), or a cluster of cognitive-behavioral cues expressing the student's insecurity and caution (uncertain, quiet and inconspicuous).

The experienced teachers' reasoning about the underestimating student (see Figure 9C) illustrates that they generally considered a higher number of cues and their relation to each other. Compared to the novice teachers (see Figure 9B), the experienced teachers focused less on the behavioral (i.e., surface) cues, but more on the knowledge-related cues and more inferential cues about the student's cognitive and motivational-affective characteristics (e.g., the student's attention and interest; i.e., deep cues).

The difference between novice teachers' reasoning (position of the mean on the *x*-axis: $M = -0.12$, $SD = 0.11$) and experienced teachers' reasoning (position of the mean on the *x*-axis: $M = 0.31$, $SD = 0.13$) regarding the underestimating student profile was statistically significant, $t(34.23) = -11.11$, $p < 0.01$, Cohen's $d = 3.52$.

The analyses of teachers' reasoning regarding the different student profiles showed that, compared to novice teachers, experienced teachers generally used a higher number of cues—of which a higher portion can be considered deep cues (e.g., about motivational-affective student characteristics)—and drew more relations between cues, thereby crafting a more comprehensive and robust reasoning than novice teachers. These observations were consistent across all individual student profiles.

5 Discussion

In this study, we delved into novice and experienced teachers' (a) judgment accuracy and (b) reasoning about observable student cues when diagnosing student profiles with varying cognitive and motivational-affective characteristics. Five different student profiles were considered: three inconsistent types (overestimating,

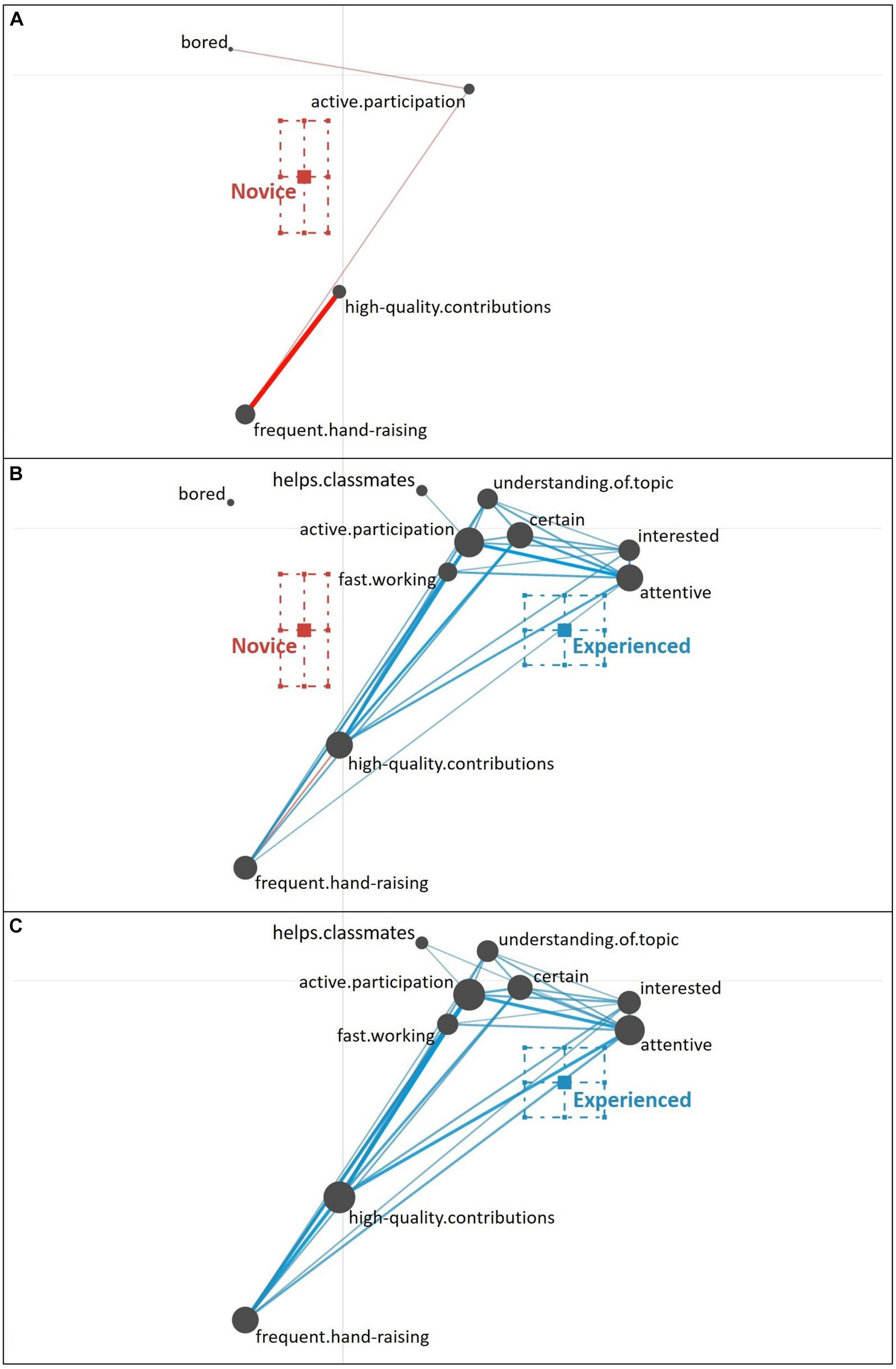

FIGURE 5
Epistemic network of teachers' reasoning regarding the strong student profile from **(A)** novice teachers and **(C)** experienced teachers, with the **(B)** comparison network showing only the differences between novice and experienced teachers' reasoning. Gray nodes correspond to cues, with node size referring to the relative frequency of their occurrence; colored edges refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations.

underestimating, and uninterested) and two consistent types (strong and struggling; Seidel, 2006; Kosel et al., 2020). Drawing on the framework of teacher professional vision, we assumed that when diagnosing student profiles, experienced teachers would make more accurate judgments than novice teachers. Over time, experienced teachers typically develop refined noticing and

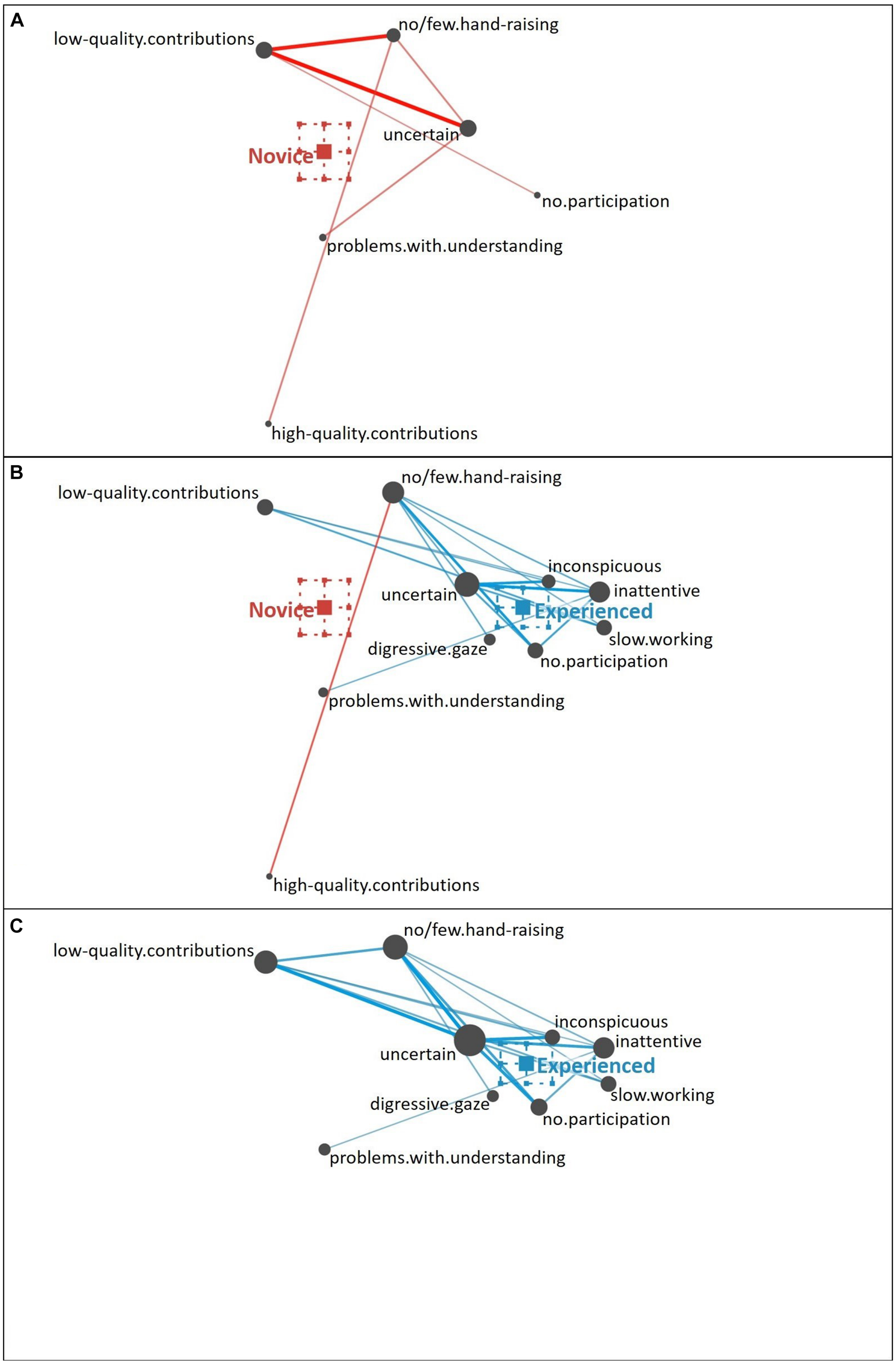

FIGURE 6
Epistemic network of teachers' reasoning regarding the struggling student profile from **(A)** novice teachers and **(C)** experienced teachers, with the **(B)** comparison network showing only the differences between novice and experienced teachers' reasoning. Gray nodes correspond to cues, with node size referring to the relative frequency of their occurrence; colored edges refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations.

reasoning skills, based on their knowledge and experience of handling diverse classroom situations (Gegenfurtner, 2020; Wolff et al., 2021). Building on prior research (Schnitzler et al., 2020), we used the method of ENA (Shaffer, 2017) to analyze differences in novice and experienced teachers' reasoning regarding the cues that they used for their diagnosing. The study adds two major

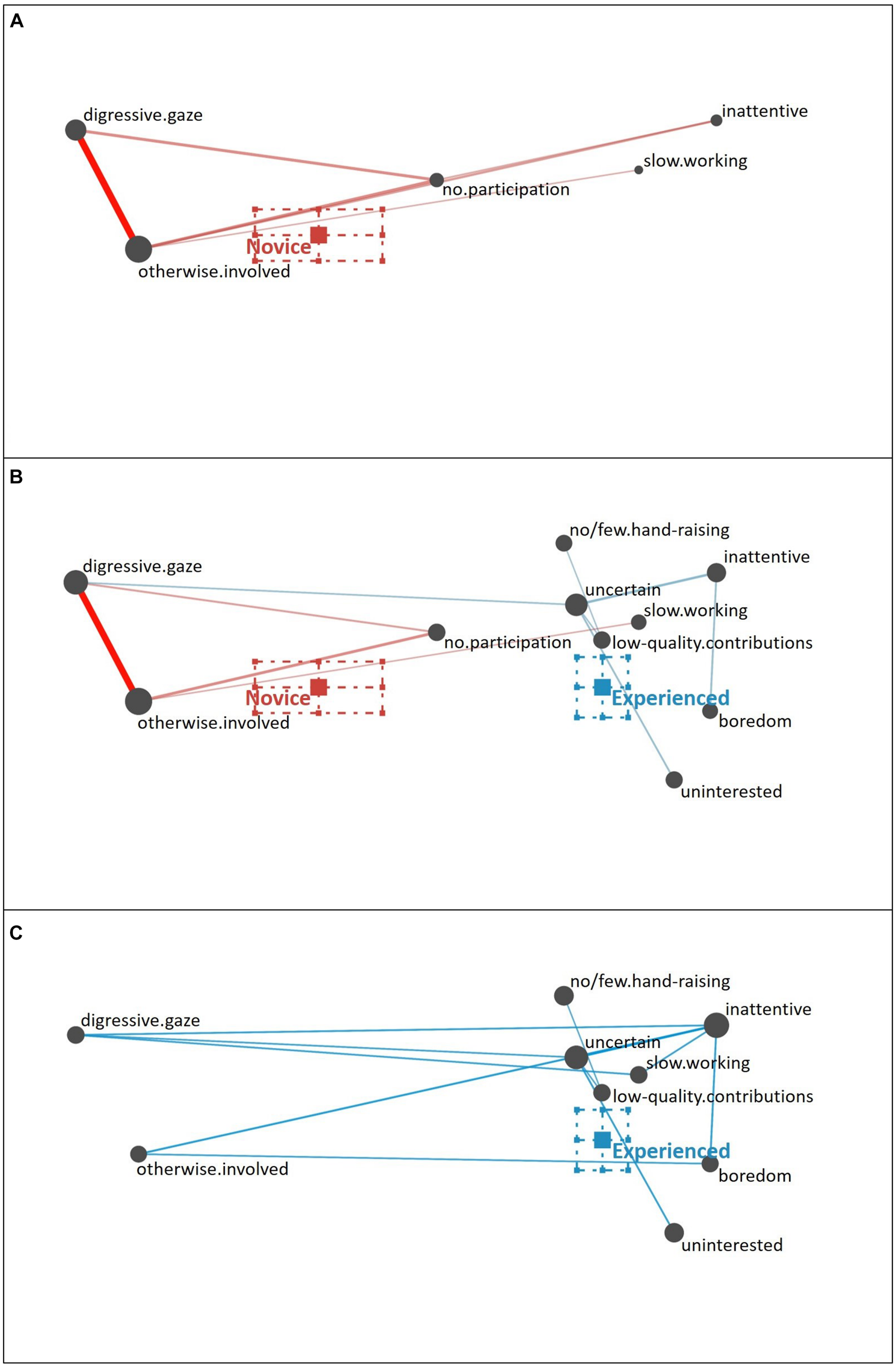

FIGURE 7
Epistemic network of teachers' reasoning regarding the uninterested student profile from **(A)** novice teachers and **(C)** experienced teachers with the **(B)** comparison network showing only the differences between novice and experienced teachers' reasoning. Gray nodes correspond to cues, with node size referring to the relative frequency of their occurrence; colored edges refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations.

findings to the research field: First, experienced teachers had a significantly higher overall judgment accuracy than novice teachers. Second, ENA showed that experienced and novice teachers differed significantly in their reasoning, both regarding the variety of considered cues and the relations drawn between the cues in their diagnosing.

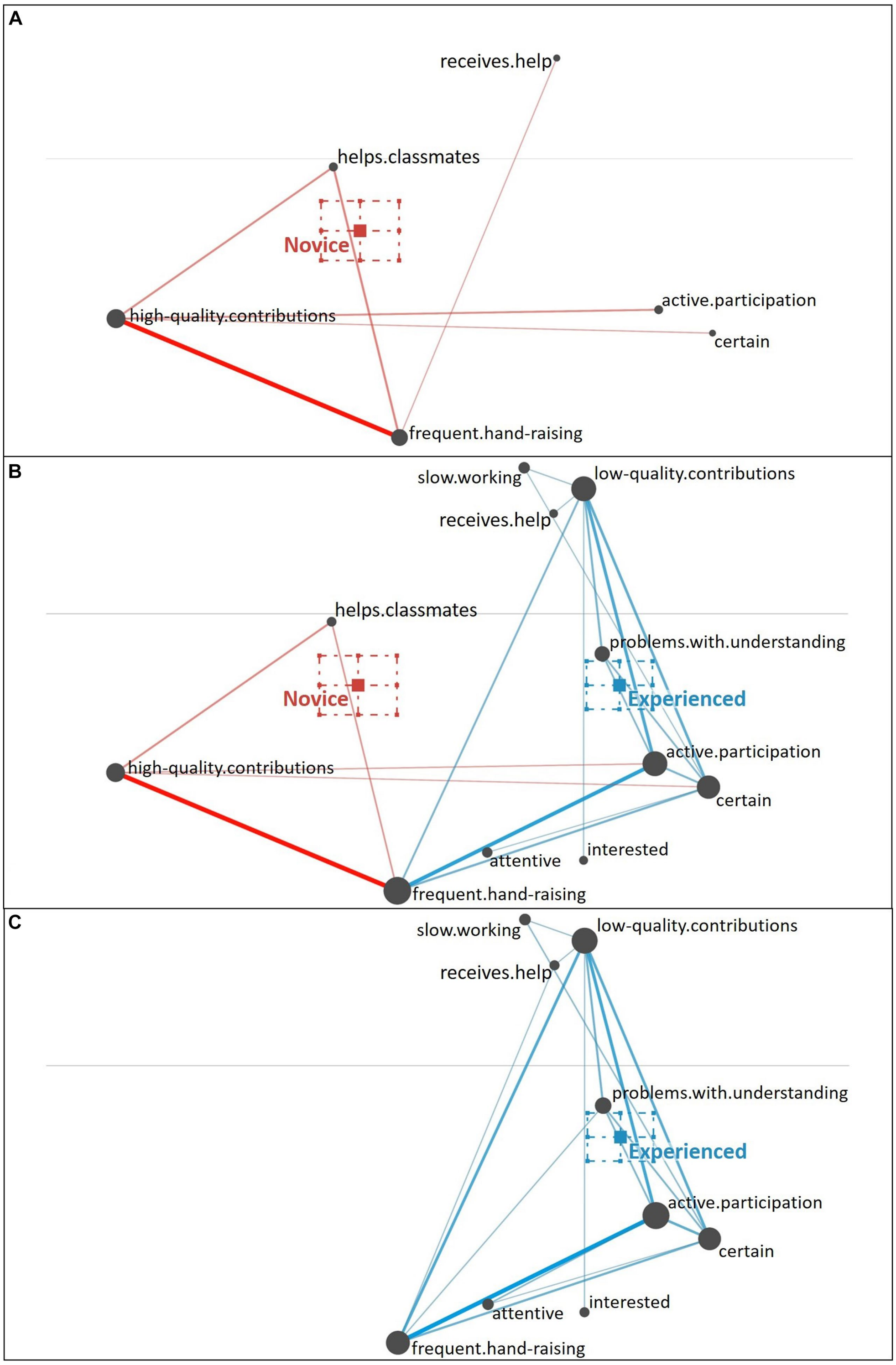

FIGURE 8
Epistemic network of teachers' reasoning regarding the overestimating student profile from **(A)** novice teachers and **(C)** experienced teachers with the **(B)** comparison network showing only the differences between novice and experienced teachers' reasoning. Gray nodes correspond to cues, with node size referring to the relative frequency of their occurrence; colored edges refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations.

5.1 The role of experience in teachers' judgment accuracy

Consistent with our initial assumption, our results confirmed that, overall, experienced teachers were able to judge student profiles more accurately than novice teachers (RQ1a). This finding aligns with theoretical models of teacher judgment (e.g., Loibl et al., 2020), which emphasize that professional experience can have a substantial effect on judgment accuracy. Through practical experience, teachers elaborate and restructure their knowledge, thereby building

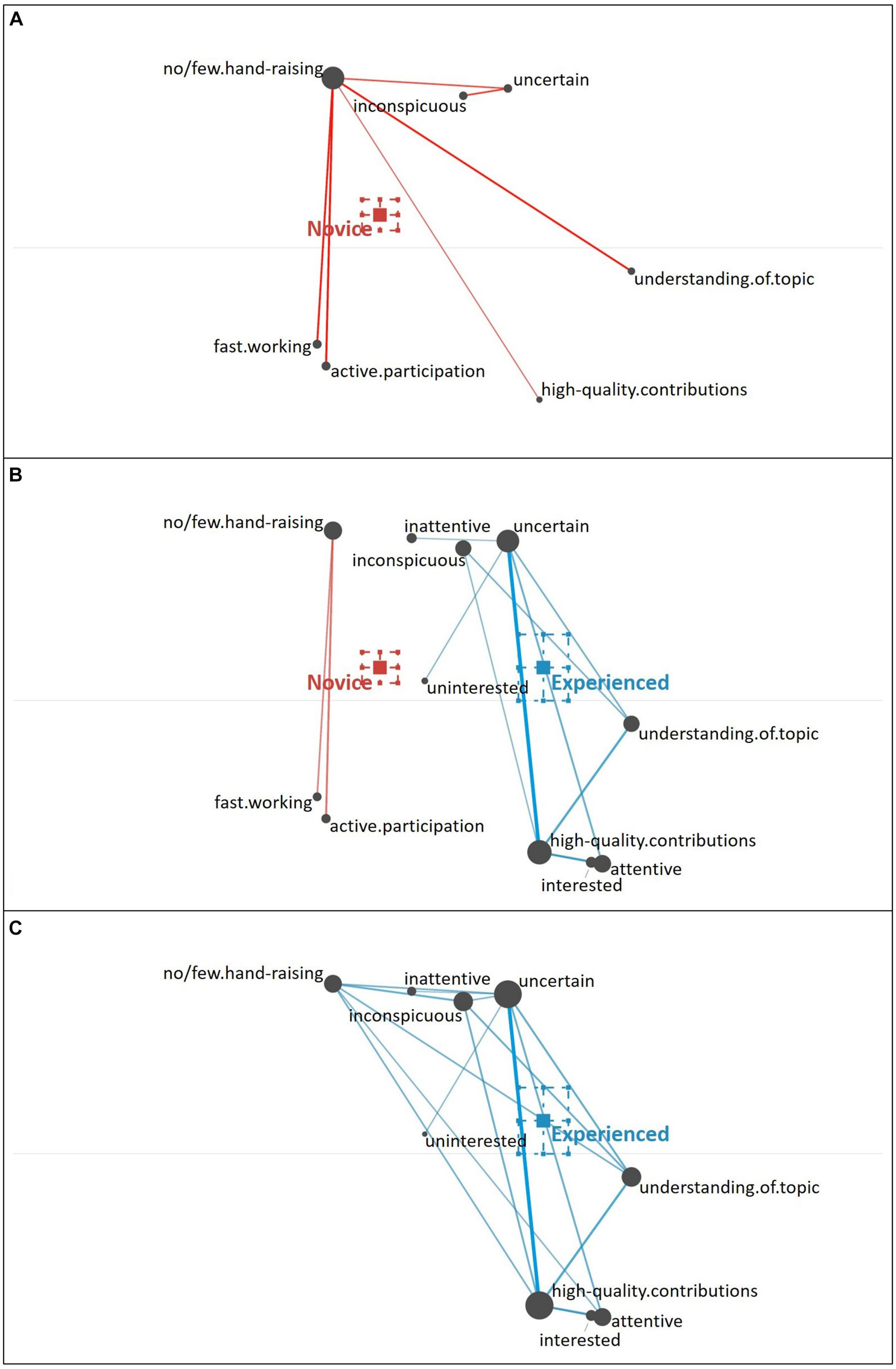

FIGURE 9
Epistemic network of teachers' reasoning regarding the underestimating student profile from **(A)** novice teachers and **(C)** experienced teachers with the **(B)** comparison network showing only the differences between novice and experienced teachers' reasoning. Gray nodes correspond to cues, with node size referring to the relative frequency of their occurrence; colored edges refer to the relations (i.e., co-occurrences) of cues, with thickness indicating the strength of relations.

higher-order knowledge representations that integrate declarative knowledge with prior experience (Boshuizen et al., 2020). Such prior experience includes encounters with a large number and variety of students. This exposure refines teachers' cognitive prototypes of typical student profiles (Cantor and Mischel, 1977; Hörstermann et al., 2010; Papa, 2016). Using this enriched professional knowledge, experienced teachers have an improved professional vision (Seidel and Stürmer, 2014; Gegenfurtner, 2020) and thus, are better equipped to make accurate judgments when diagnosing student profiles.

However, the results of the post-hoc analysis indicated that the difference between experienced and novice teachers' judgment accuracy was not significant at the level of individual student profiles (RQ1b). Examining the descriptive results, experienced teachers clearly had a higher mean judgment accuracy for each student profile compared to novice teachers. However, within both teacher groups, there was substantial variance in the judgment accuracy per student profile, as indicated by standard deviations. The results suggest that while many experienced teachers can accurately judge student profiles, a significant number also struggle to make accurate judgments. Other research has emphasized as well that despite the higher average judgment accuracy that is associated with increasing experience, there are also variations in experienced teachers' judgment accuracy (Jacobs et al., 2010). The depth and quality of teachers' knowledge might depend on their formal training, ongoing professional development, and individual experiences (e.g., regarding classroom challenges, student demographics, etc.). However, as pointed out by Schnitzler et al. (2020), also novice teachers can achieve high judgment accuracy when diagnosing student profiles. Variations in novice teachers' knowledge might be explained as well by their individual education, initial practical experience in teaching, but also individual person characteristics that are not related to professional knowledge (e.g., self-concept and interest; Sorge et al., 2019). However, despite the variance in the judgment accuracy per student profile within both groups of experienced and novice teachers, experienced teachers (a) showed a higher baseline, higher mean, and lower standard deviation in their overall judgment accuracy (see boxplot in Figure 2) and (b) higher mean judgment accuracy per student profile. Thus, we consider the overall results of this study as support for the assumption that experienced teachers—through their elaborated knowledge and improved professional vision—can diagnose student profiles more accurately than novice teachers.

Interestingly, we found that experienced teachers performed particularly well in accurately judging some of the inconsistent student profiles, namely the uninterested and the underestimating student profile. This is in line with the finding of Südkamp et al. (2018), who initially assumed that making a holistic judgment based on inconsistent patterns of cues for cognitive and motivational-affective characteristics might result in lower accuracy; however, they empirically found that teachers in their study were not better at diagnosing consistent profiles compared to inconsistent profiles. Based on the evidence, we speculate that one factor in teachers' development of cognitive prototypes concerning student profiles might be the frequency with which the student profiles occur in regular classrooms (i.e., exemplarity; see Fischer et al., 2022): As reported by Kosel et al. (2020), approximately 35% of students in a large sample of 9th-graders exhibited an underestimating profile. This finding was consistent in two different school subjects (i.e., mathematics and language arts), suggesting that the underestimating profile might be a common profile to observe in secondary school students; by contrast the frequency of other profiles varied across the two subjects. Experienced teachers, exposed to specific student profiles, might refine their cognitive prototypes of students over time, resulting in a refined professional vision and improved judgment accuracy in diagnosing the respective student profiles.

5.2 The role of experience in teachers' diagnostic reasoning

To understand why experienced teachers achieve higher judgment accuracy in diagnosing student profiles, exploring their diagnostic reasoning can provide relevant insights into *how they reason* and *about which cues* they reason (Herppich et al., 2018; Loibl et al., 2020). Using ENA, we found (RQ2a) that experienced teachers, compared to novice teachers, used (a) generally a higher number of cues of which (b) a higher portion can be considered deep cues, for example, about motivational-affective student characteristics; moreover, experienced teachers (c) drew more relations between observed cues, thereby crafting a more comprehensive and robust reasoning than novice teachers, and did so (d) across all individual student profiles (RQ2b).

As already reported by Schnitzler et al. (2020), the novice teachers in our sample primarily referred to behavioral cues, such as hand-raising or active participation, and additionally considered cues about students' knowledge in their reasoning. Especially the behavioral cues can be regarded as surface cues because they are focused on a directly observable level of student behavior (see Brunswik, 1955; Loibl et al., 2020). By contrast, as found in the present study, experienced teachers more frequently integrated deep cues into their reasoning, such as recognizing when a student is uncertain, inattentive, or interested. Such deep cues refer to a rather inferential level of the students' cognitive and emotional engagement and are not necessarily directly observable (see Brunswik, 1955; Loibl et al., 2020). Experienced teachers seem to leverage surface cues (e.g., hand-raising) to infer deep cues (e.g., certainty), by using additional information to make inferences about not directly observable motivational affective student characteristics (e.g., interest). It might be assumed that these inferences require cognitive resources on the side of the teacher; however, the higher number of cues and the higher number of relations drawn between cues indicate that experienced teachers are very efficient in noticing and reasoning about cues. Thus, relations between observable cues on the surface and the deep level might be stored as part of teachers' cognitive prototypes, which can be used as efficient heuristics when processing information during noticing and reasoning processes (see Kahneman and Klein, 2009; Boshuizen et al., 2020).

Such findings are consistent with previous expert-novice studies of teachers' professional vision (Van Es and Sherin, 2010; Seidel and Stürmer, 2014; Gegenfurtner, 2020). These studies have collectively emphasized that experienced teachers generally outperform novices in both identifying (noticing) and interpreting (reasoning) cues that are relevant to teaching and learning (Gegenfurtner, 2020). Our findings are also consistent with the findings of Jacobs et al. (2010) that novice teachers struggle to identify and interpret deep cues (e.g., regarding students' level of understanding), which a large majority of experienced teachers can identify and reason about. As in Jacobs et al. (2010) study, novice teachers in the present study may have also faced challenges in gaining sufficient insights from observing student behavior. Compared to experienced teachers, novice teachers might usually not have yet accumulated the required knowledge and experience for drawing more in-depth inferences from their observations (i.e., about deep cues) and thus, are more likely to remain on a surface level of reasoning (i.e., about surface cues).

We also speculate that the differences found between novice and experienced teachers' reasoning in our study might partially trail back to novice and experienced teachers' noticing of cues—which was, however, not investigated in the present study. Differences in novice and experienced teachers' noticing processes have been examined by eye-tracking research which focused on how novice and experienced teachers observe and respond to student behavior. Experienced teachers typically exhibit an extended visual monitoring behavior, encompassing a larger subset of students (Kosel et al., 2021). Their monitoring behavior is more advanced, enabling them to gather detailed, nuanced information about diverse students in a short timeframe (Dessus et al., 2016; Verbert et al., 2016; Kosel et al., 2021, 2023). In contrast, as found by Dessus et al. (2016), novice teachers experience an increased cognitive load during monitoring students, resulting in a more limited focus on a smaller group of students. Research by Karst and Bonefeld (2020) shows that teachers' judgment accuracy improves with a uniform distribution of attention across students, which emphasizes the impact of noticing processes on teachers' judgment accuracy and, presumably, also their reasoning.

In addition to differences in the type of cues, our exploratory network analysis of teachers' diagnostic reasoning indicated that experienced teachers drew more relations between observed cues, thereby crafting a more comprehensive and robust reasoning than novice teachers. For example, novice teachers' reasoning about the overestimating student was not necessarily specific to the overestimating profile but indicated potential confusion with the strong profile. As reported by Schnitzler et al. (2020), their indeed tended to confuse the overestimating and the strong student profile. Besides their focus on behavioral cues (e.g., frequent hand-raising, active participation), one factor in novice teachers' confusion was their misinterpretation of the quality of the student's contributions (e.g., misinterpreting the overestimating student's low-quality contributions as high-quality contributions). Moreover, by comparison, an additional difference is that expert teachers validated their observations about overestimating students by relating a broader number and variety of cues about cognitive and motivational-affective student characteristics in their reasoning. This pattern was observable across all different student profiles. As suggested by the lens model (Brunswik, 1955), experienced teachers might tend to correlate various cues, thereby checking the cues' validity and making a probabilistic yet informed judgment. This is in line with research on expert decision-making in other areas than teaching (e.g., medicine), which indicates that domain experts (i.e., more experienced professionals in a specific domain) are better at collecting a variety of cues in a short time and identifying valid cues related to target characteristics (Elstein et al., 1978; Herbig and Glöckner, 2009; Papa, 2016). We speculate that, by contrast, novice teachers' less comprehensive and, thus, less robust reasoning might be more susceptible to premature judgments (known as premature closure in medical diagnosing; e.g., Norman et al., 2017) or otherwise biased judgments (e.g., the halo effect; Fiedler et al., 2002).

5.3 Limitations and future research

This study significantly advances research on teachers' accuracy in judging student profiles. By empirically examining the differences in judgment accuracy and diagnostic reasoning between novice and experienced teachers, we employed the methodology of ENA to shed light on these differences. However, some limitations need to be addressed in future research to enhance evidence even further.

First, this study did not delve deeply into how student characteristics and profiles are manifested in students' behavior and only took preliminary steps in this direction. The study did not address questions such as how students' interest effectively manifests in hand-raising (see Böheim et al., 2020) or how uninterested students might obscure their low interest through adequate procedural display while in fact engaging only in mock participation (see Bloome et al., 1989; Vors et al., 2015). Subsequently, more in-depth investigations of the valid behavioral cues of different student profiles may further elucidate the relationship between experienced and novice teachers' noticing of behavioral cues and their judgment accuracy (Herppich et al., 2018; Südkamp et al., 2018). Second, our operationalization of diagnosing consists of observing a classroom situation. In contrast, teachers' diagnosing in real classroom situations often happens while interacting with students and engaging in intervention activities, such as instruction and classroom management. We argue that investigating diagnosing through teachers' observation of video stimuli is advantageous in terms of standardizing the diagnostic task and setting, which is why this approach is frequently used in research on teachers' diagnosing and professional vision (e.g., Stahnke and Blömeke, 2021). However, we acknowledge the role of research investigating diagnosing while interacting with students (in simulations, e.g., Kron et al., 2021; or in real classrooms, e.g., Südkamp et al., 2018) as well as the relation between diagnosing and intervention activities. Third, a notable limitation of our study is the lack of diversity in the authentic classroom video sequences used. We used a single video sequence, which raises questions about the generalizability of our findings. The consistency and replicability of our findings may vary if using different video sequences with different students. This highlights the potential need for further research using varied video samples to validate and solidify our current findings. Fourth, in our study, teachers were primed to include not only consistent but also inconsistent student profiles in their judgments because they were prompted to diagnose the five initially introduced profiles of student characteristics. Moreover, since the five profiles had to be assigned to five students in the video, teachers' judgments and thus the measurements of teachers' diagnostic accuracy and reasoning were not independent across the different students. Thus, our results might not be generalizable to teachers' judgment accuracy regarding consistent and inconsistent student profiles in other settings. Further studies should use an unmatching number of profiles and students to be diagnosed (e.g., more or less students than profiles). In addition, research might address processes of cue comparison as well as teachers' revisions of their judgments to better understand comparisons and references made when diagnosing multiple students. Fifth, another key limitation of our study is its limited sample size. This restricts the generalizability of our findings, as a larger, more diverse sample might reveal additional patterns or nuances, especially in teachers' reasoning. Consequently, broader investigations are needed to confirm the robustness and applicability of our conclusions.

While acknowledging these limitations, our study underscores the importance of further investigating teachers' judgment accuracy and reasoning when diagnosing student profiles and thereby sets the stage for future research avenues. For example, the influence of different features of student "cases" on teachers' diagnosing might be further investigated to understand how those features contribute to making a student case difficult to reason about. Our results indicate that a higher frequency (i.e., exemplarity) a specific student profile in real classrooms might facilitate experienced teachers' judgment accuracy because they have gained a lot of experience with students that match this frequent student profile. However, also other features of student cases and classroom situations might be worth exploring, such as the complexity of information (i.e., the amount and connectivity of information that needs to be processed), especially in terms of the salience of relevant cues (Fischer et al., 2022).

Moreover, future research might elucidate the sequence in which novice and experienced teachers employ cues for diagnostic reasoning. As inferred from our results, experienced teachers seem to leverage several surface cues, such as hand-raising, to infer deep cues, such as interest, thereby constructing more robust reasoning than novice teachers. Within the realm of educational process data mining, tools, such as the Heuristics Miner (Weijters et al., 2006), can be instrumental in discerning the most prevalent paths or sequences of cues and identifying outliers in teachers' reasoning, while considering the chronology of cue utilization using Petri-Nets and hidden Markov models (Namaki Araghi et al., 2022). In addition, researchers could implement more complex mediator models in their analyses to explore in detail how different behavioral cues are statistically relevant in predicting or mediating teachers' accuracy of judgment. This will require a more fine-grained and weighted coding of behavioral cues (since some cues are more or less diagnostic) and larger sample sizes.

Another potential direction for future research is leveraging the findings of this study to enhance the judgment accuracy and diagnostic reasoning of novice teachers during training sessions. For example, training sessions in study programs can discuss the outcomes of the network analysis. Future studies using data mining can contribute with further information about successful diagnostic approaches. This integration provides novice teachers with a comprehensive *blueprint* that illustrates the complex ways in which more experienced teachers use student cues in their reasoning to achieve higher accuracy in their judgments. Studies focusing on investigating perceived case difficulty conceptualized by features of student cases can further inform teacher education, for example, regarding potential sequencing strategies of different cases to facilitate novice teachers' systematic training (see Fischer et al., 2022).

5.4 Conclusion

This study, anchored in the framework of teacher professional vision, delved into the diagnosing of experienced and novice teachers in terms of reasoning about student cues and judging profiles of student characteristics. By analyzing teachers' judgment accuracy and exploring cues utilized in teachers' written diagnostic reasoning with epistemic network analysis, our study revealed two central findings. First, experienced teachers exhibited a higher overall accuracy in judging the five student profiles. Second, experienced teachers related a higher number of cues, especially deep cues (behavioral cues that are not directly observable), in their reasoning, which was consequently more comprehensive and robust compared to the reasoning of novice teachers. This research underscores the nuanced development of professional skills, such as diagnosing, with professional experience.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. 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. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

CK: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. EB: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. TS: Conceptualization, Funding acquisition, Project administration, Resources, 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.

Publisher's note

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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

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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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