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Research paper

Student teachers' and experienced teachers' situation awareness and professional vision in real-life classrooms

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ABSTRACT

We developed the integrated model of teacher's attention to examine teachers' a) situation awareness of the overall classroom and b) professional vision of individual pupils. Using mobile eye tracking in real classrooms, we analyzed teachers' eye movements using a novel metric, the Gaze Relational Index. The findings indicated that situation awareness involves shorter and more frequent gazes, while professional vision requires fewer but longer gazes. Experienced teachers showed faster and more varying visual attention compared to student teachers. This study provides valuable insights into visual processing in real-life classrooms, addressing the gap left by previous studies.

1. Introduction

Multiple simultaneous events and processes taking place in the classroom offer a jungle of triggers for a teacher to attend to. Teaching is usually organized for 20–40 students in the same classroom, which means that teachers should be simultaneously aware of the overall classroom situation and focus on individual pupils' learning processes as noted in many studies (e.g. Daumiller et al., 2025). This challenges teachers' attention in a way which has been studied in the research traditions of situation awareness (Endsley, 1995, 2000) and professional vision (van Es & Sherin, 2002). During the last decade, several educational studies have analyzed various aspects of teachers' professional vision (Keskin et al., 2024), but studies focusing on teachers' situation awareness are rare. In particular, studies including simultaneous examination of these two aspects of teachers' visual attention in real classroom settings remains underexplored, and with this study we aim to narrow this gap.

As concepts, situation awareness and professional vision partly overlap as they both refer to the ability to notice and reason the environment in a way that is typical for professionals and highly linked to professional knowledge. The main difference in empirical studies applying these concepts has been that situation awareness is used to refer to representations of the whole situation. Situation awareness enables attention to events and features in complex professional situations that are not in the focus of immediate actions, yet important for accomplishing the task (Endsley, 1995), such as managing the overall classroom. Professional vision has been used to refer to the perceptual ability to notice and interpret events and features, which are in the focus of current activity. In educational studies professional vision is mainly applied in describing teachers' attention on and knowledge-based reasoning about pupils' learning (Jacobs et al., 2010; Seidel & Stürmer, 2014; van Es & Sherin, 2002). Due to these differing intentions and goals that influence attention to situational features, we examine whether situation awareness and professional vision require distinct types of visual processing in terms of focusing teachers' gaze. Focusing solely on professional vision without considering the challenge of situation awareness underestimates the complexity of teachers' attentional processes in classroom teaching. In laboratory settings, when interpreting classroom videos, participants can choose whether to focus on individual students' learning or on the classroom as a whole (Daumiller et al., 2025), but in real classroom situations teachers must attend to both levels simultaneously.

Both situation awareness and professional vision develop during increasing professional experience, particularly in deliberate practice, intentionally focusing on developing professional skills (Endsley, 2018; Ericsson, 2018; Gegenfurtner et al., 2020, 2023; Wolff et al., 2020) leading to possible differences between experienced teachers and novices (e.g., Berliner, 1994). Goodwin (1994) has emphasized that the development of professional vision is not mere individual learning but a process socialization into professional culture. Thus, it is important to investigate student teachers' and experienced teachers' differences in situation awareness and professional vision.

In this study, we created the theoretical and methodological “Integrated Model of Teacher's Attention” to combine these two levels of

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teacher's attention in a real classroom situation. Both concepts, professional vision and situation awareness, refer to rich professional knowledge and skills developed in formal training and through practical experience, and are shared within professional communities. However, in this study we only focus on one aspect of these concepts, visual attention, in a way which is necessary for actual realization of professional vision and situation awareness in complex real-life teaching situations. Some of these broader aspects, such as knowledge-based reasoning of professional vision, have been analyzed from the same data in our earlier study (Pouta et al., 2020). In this study we employ mobile eye tracking in real classrooms during the individual work phase of the lesson to investigate differences in teachers' gaze behavior in episodes of situation awareness of the overall classroom and episodes of professional vision on individual pupils. In addition, we investigate differences in gaze behavior in these levels between experienced teachers and student teachers. Previous studies have found remarkable differences between novice and experienced teachers' visual processing, more specifically in how frequent (amount) and how long (duration) the fixations are (Holmqvist et al., 2011). This study utilizes a novel metrics recently applied in classroom studies, the Gaze Relational Index (GRI) that represents the ratio of the mean fixation duration to the mean number of fixations (Lowe & Boucheix, 2016).

1.1. Situation awareness and visual expertise

Teaching simultaneously many pupils sets a challenge for a teacher to be aware of the overall classroom situation, a process similar to the one that is extensively studied in research on situation awareness in other professional fields. However, situation awareness has only recently been proposed to be applied in analyzing classroom teaching (Miller, 2011; Wolff et al., 2020). The concept originates from Endsley's (2000) work, in which situation awareness has been described as "knowing what is going on around you" (p. 2). Research on professional performance in fields such as piloting and surgery has highlighted the importance of situation awareness in understanding the overall situation (Endsley, 1995; Graafland et al., 2015). For example, when a surgeon is conducting a demanding specific task during an operation, it requires an intensive focus of attention on this specific object, but there are many crucial things outside its scope that must be considered simultaneously to manage the surgery successfully (Schulz et al., 2013). In a classroom setting, keeping the overall classroom situation in mind and being alert to it resembles a situation in which a teacher seems to have "eyes in their back" (Miller, 2011).

As such, situation awareness means certain focus that involves more than perceiving one's surroundings. It requires a) perception of the elements in the environment over a span of time and space, b) understanding the perceived information in connection to goal of the action and c) anticipating future states of the situation (Endsley, 1995). Through this process, "the decision maker forms a holistic picture of the environment, comprehending the significance of objects and events" (Endsley, 1995, p. 37). As the situation is constantly changing, situation awareness requires continuous maintenance and evaluation of what, in this state of the environment, is optimal to focus on. This skill is essential for classroom management (Wolff et al., 2020) and the flow of teaching (Miller, 2011).

Attentional processes are an essential part of situation awareness. The core of situation awareness is not to attend to everything but to attend to the essential features of the situation regarding the situation and the goal of the action (Endsley, 2000). It also means having the ability to ignore the features of a situation which are less essential from the current aims of teaching (Miller, 2011). As Endsley (1995) describes:

SA is largely affected by a person's goals and expectations which will influence how attention is directed, how information is perceived, and how it is interpreted. This top-down processing will operate in tandem with bottom-up processing in which salient cues will activate appropriate goals and models. (p. 49)

Such selective process is possible because of well-developed mental models that are typical of experienced professionals (Endsley, 2000, 2018). Endsley (2018) described how prototypical states of mental models (i.e., schemas) are created based on not only knowledge but also experiences in similar situations.

In educational context, Wolff et al. (2020) describe how experienced teachers' awareness of the classroom is characterized by their automatized scanning of the whole classroom situation. For novices monitoring the same situation is known to cause greater cognitive load as the process is yet more conscious (Wolff et al., 2020). Such cognitive load makes novices more vulnerable to cognitive tunneling, in which they narrow their attentional field when executing a demanding task (Dirkin, 1983). Novice teachers are also known to be more prone to attend to salient triggers of the situation, such as sudden movements of the pupils (Seidel et al., 2021; Wolff et al., 2016).

1.2. Professional vision and visual expertise

Guiding individual pupils' learning processes requires teachers to actively attend to pupils' thinking, a practice often conceptualized as professional vision or professional noticing, with different emphases (Louie, 2018; Sherin et al., 2024). Originating in Goodwin's (1994) work on courtroom interaction and archaeology, professional vision refers to 'socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group' (p. 606). It thus captures the sociocultural dimensions that shape the process. As Goodwin (1994) further notes, 'such vision is not a purely mental process but instead is accomplished through the competent deployment of a complex of situated practices in a relevant setting' (p. 626). Professional vision can therefore be understood as a socially constructed cognitive process, continuously shaped through interaction.

In educational studies professional vision has often been described as a process of selective attention and knowledge-based reasoning (Seidel & Stürmer, 2014). It includes three components: a) noticing a pupil's processing, b) interpreting the cues of pupils' processing (van Es & Sherin, 2002), and c) making decisions about actions (Jacobs et al., 2010). The process is always context-dependent because professional vision is a situated process (Nückles, 2020), focusing on particular events of the lesson. The situatedness has been studied in relation to, for example, subject specificity (Blomberg et al., 2011; Pouta et al., 2020), phases of the lesson (Jarodzka et al., 2023), teachers' knowledge about particular students (Horlenko et al., 2024), and a teacher's interaction with pupils (McIntyre et al., 2017). In a teacher's professional vision classroom interactions are in a central role. As described by Sherin et al. (2008), "More specifically, teachers' professional vision involves the ability to notice and interpret significant interactions in a classroom" (p. 28).

Professional vision is a strongly knowledge-guided process (Stürmer et al., 2013), and the effectiveness of professional vision is dependent of the knowledge base of the teacher (Grub et al., 2022). The knowledge base needed for professional vision is multifaceted and many theoretical descriptions lean on Shulman's (1986) description of knowledge constructions that include pedagogical content knowledge (PCK), pedagogical knowledge (PK) and content knowledge (CK) (e.g. Lachner et al., 2016; Seidel et al., 2024). However, professional vision is not just tied to the amount of such knowledge but depends on organization of the knowledge that enables more effective adaptation of it in practice (Seidel et al., 2024). These shortcuts for the use of knowledge, such as curriculum scripts (Putnam, 1987), classroom management scripts (Wolff et al., 2020), and teaching scripts (Moberg et al., 2025) develop not just through formal training but also through deliberate practice and experience. Hence, in cognitive scripts knowledge is organized to teaching-relevant events, which makes functioning routine situations efficient (Seidel et al., 2024).

Enhanced professional vision is based on culturally shared coding system which makes it possible for experienced professionals to reduce the complexity of the situation (Goodwin, 1994; Louie, 2018) and to disregard features in the teaching situation which are not important for the aims of the activity (Gegenfurtner et al., 2023). Numerous studies have demonstrated that experienced teachers are more attuned to attend to pupils (e.g., McIntyre et al., 2017; McIntyre et al., 2019; Stahnke & Blömeke, 2021; Stürmer et al., 2017; van den Bogert et al., 2014). Focusing on pupils instead of other features of the situation has been found to create improvement in the quality of a teacher's professional vision (e.g. Hogan et al., 2003; Sherin & Han, 2004).

1.3. Eye movements reflecting visual attention

Visual attention holds a particular role in both situation awareness and professional vision in real-life classroom context, due to the abundance of visual cues present and the significance of visual processing in interactions with pupils, and because of the communicative nature of gaze. Teachers frequently employ their gaze strategically to direct pupils' focus, thereby facilitating shared attention on a common target (Pouta et al., 2020).

According to Just and Carpenter's (1980) eye–mind hypothesis, when a person fixates an object, they are also processing it. This has also been criticized, as a fixation does not always guarantee mental processing. In a situation requiring focus on intentional processing, such as in teaching, the context requires a teacher's mindful perceptions and reasoning of situational cues. Eye tracking method offers a possibility to examine visual attention as it captures a person's eye movement, i.e. fixations and hence, enables investigating visual attention.

Gegenfurtner et al. (2023) theory of visual expertise describes expert visual processing which includes selecting visual information, ignoring visual information, knowledge-based noticing, extending the visual field through parafoveal processing, organizing image chunks, integrating the information with stored knowledge, using visual practices to interact with the environment, and monitoring the entire process. Hence, a teacher not only automatically attends to appearing triggers in the environment through a cue-driven bottom-up trait but also actively affects the possibilities to access visual information based on their volitional, knowledge-guided top-down trait (Gegenfurtner et al., 2023).

Studies in laboratory settings have revealed that more effortful processing is indicated by long fixations or a high number of fixations, whereas a low number of fixations is often connected to effective visual processing, which is a feature of experienced professionals (Holmqvist et al., 2011). Experts have consistently shown shorter mean fixations than novices (Gegenfurtner et al., 2011). However, in ecologically valid settings, indications of fixation duration and count are not as straightforward as in laboratory settings. The relationship between the duration and count of fixation in such settings has revealed interesting features of professionals' visual attention. Studies in dynamic situations, such as football (Williams et al., 1994) and aviation (Kasarskis et al., 2001), have shown that the efficiency of an expert's visual attention is indicated by the combination of more fixations that are shorter with duration. On the other hand, longer but fewer fixations of an expert compared to novices does not necessarily indicate difficulty in processing but the use of a larger visual span, which also allows the processing to be more efficient (Holmqvist et al., 2011). Hence, it seems that the relationship between fixation duration and count reveals two types of visual attention.

Recent study by Daumiller et al. (2025) of preservice teachers showed that teachers' goals directed at students and the classroom involve different types of gaze behavior. According to the study, teachers' goals that are directed at individual students are associated with more and longer fixations whereas goals towards the overall classroom include shorter fixation durations on individual students (Daumiller et al., 2025).

To investigate the ratio between the mean fixation duration and the mean number of fixations, a novel GRI approach has recently been used in visual processing studies (Gegenfurtner, Boucheix, et al., 2020; Kosel et al., 2023; Lowe & Boucheix, 2016). According to Lowe and Boucheix (2016), longer fixation durations and lower fixation counts (GRI over 1) indicate intensive attention, whereas shorter durations and higher counts (GRI under 1) indicate more exploratory, distributed processing, which is called scanning. Hence, GRI reflects two different types of visual processing that we believe can in a classroom context indicate different types of focus of visual attention. As situation awareness requires constant updating of the information from the overall situation (Endsley, 2000), we assume that it is dominated by the scanning type of gaze at pupils. In contrast, professional vision requires focused attending to a particular pupil's activity (Hogan et al., 2003; Sherin & Han, 2004) by using coding (e.g. grouping students according to ability) shared in processional culture of teachers (Louie, 2018; Lundgren, 1974). Therefore, we assume that it is dominated by an intensive type of gaze.

1.4. Integrated model of a teacher's visual attention

The optimal combination of classroom management and pupil scaffolding necessitates that teachers meaningfully shift their focus of attention between these two levels. This study aims to develop an integrated model of teachers' focus of attention in a real classroom by combining Endsley's theory of situation awareness (Endsley, 1995) with theory of professional vision adapted in educational context (Jacobs et al., 2010; Seidel & Stürmer, 2014; van Es & Sherin, 2002). Although these frameworks share conceptual similarities, the proposed theoretical model seeks to adapt their principles specifically to the classroom setting, where they offer complementary insights into teachers' focus of attention. We hypothesize that the different core aims of situation awareness and professional vision processes are also reflected in the visual processing of information in dynamic real-life classroom situation. The integrated model of teacher's attention is illustrated in Fig. 1.

With situation awareness a holistic picture of the environment is formed, which requires directing attention to the features essential for the goal of the action, using appropriate mental models and anticipating the future states of the situation to select a functional problem-solving strategy (Endsley, 1995). As can be seen in Fig. 1, situation awareness leads to maintaining knowledge of the overall situation. In a classroom, maintenance of situation awareness is essential for understanding the whole classroom situation, which enables estimation of the need for classroom management, targeting individual guidance (see Endsley, 2000), and guiding the situation towards the goal without distractions to the flow of teaching (Miller, 2011). Accessing applicable information about the overall situation requires utilizing a wide visual field, which in teaching resembles situation in which the teacher is observing the whole classroom and not focusing on guiding a particular pupil. A wide visual field offers numerous visual triggers that the teacher needs to select for attention and reason. This is likely to activate a teacher's cue-driven, bottom-up processing, which sets a challenge for a teachers' effective actions (Gegenfurtner et al., 2011, 2023). Because the aim of situation awareness is to maintain understanding of the overall situation it is likely to include exploratory and distributed gaze behavior. Lowe and Boucheix (2016) described that such scanning type of gaze means shorter durations and higher counts of fixations. This could be assumed to be a characteristic of situation awareness.

As presented in Fig. 1, in professional vision, a teacher gathers in-depth information about a pupil's learning process during interaction by noticing cues related to the pupil's thinking, interpreting their thinking based on these cues (van Es & Sherin, 2002), and deciding how to instruct (Jacobs et al., 2010). This process requires a focus on meaningful areas that reveal the pupil's processing, such as their materials or facial expressions. Such tasks that require intensive selective attention lead to a narrowed visual focus on the essential features of the situation, and unessential features being ignored, which is characteristic of skilled experts (Gegenfurtner et al., 2023; Miller, 2011). Lowe and Boucheix (2016) stated that intensive attention includes longer fixation durations and lower fixation counts and indicates focused processing.

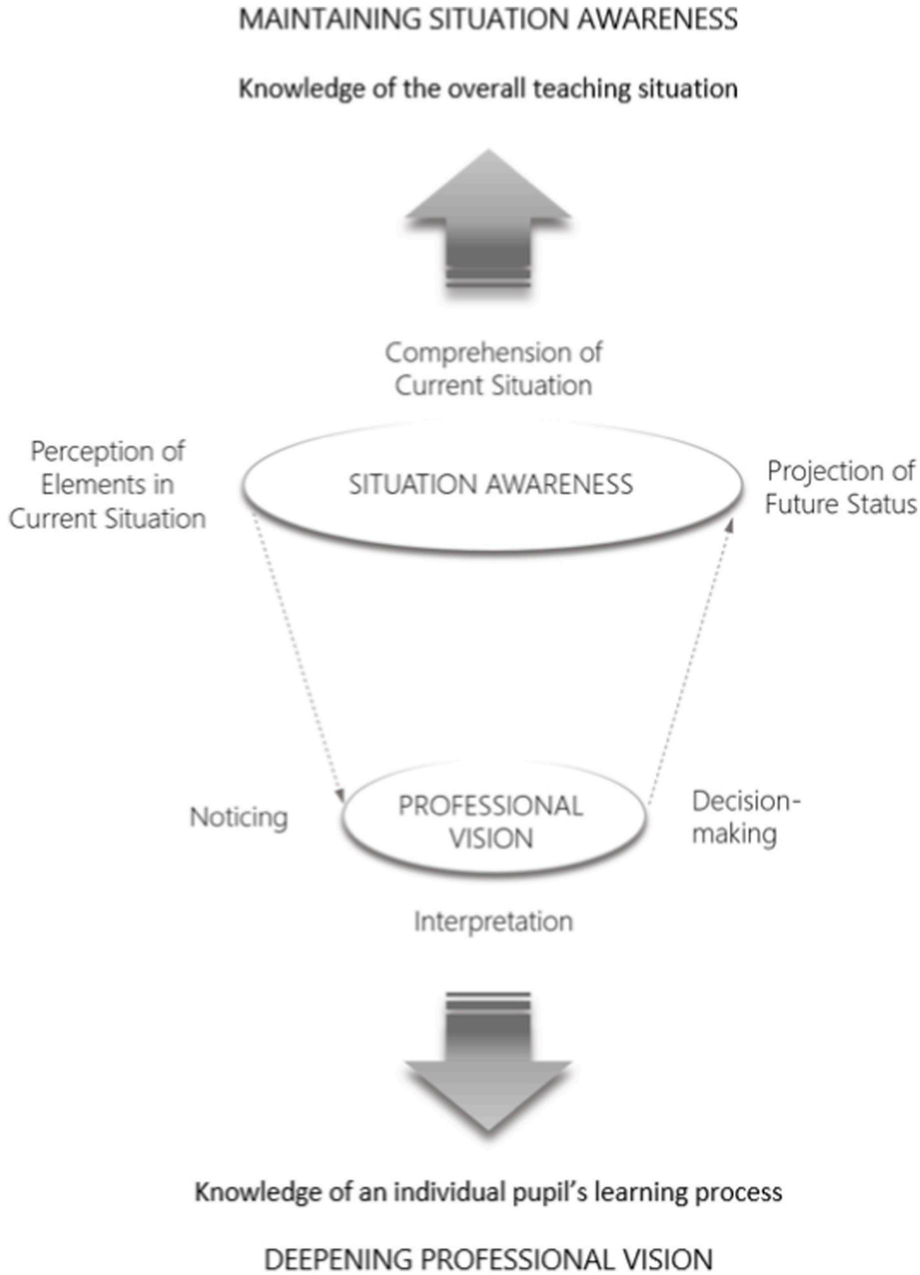

Fig. 1. Integrated model of a Teacher's visual attention.

Therefore, intensive attention could be assumed to be a characteristic of professional vision.

The theoretical and methodological model aims to describe the emphasis of the focus of attention when attending to an overall classroom situation and individual pupil's processing. Hence, it does not claim situation awareness and professional vision to exclude each other, but rather to appear with varying emphasis in different situations and supplementing the teachers' attention process in real classroom situations.

Examining professional vision and situation awareness in authentic settings with an in-action observer design is essential, as both situation awareness and professional vision are skills situated in socio-culturally formed professional context rather than mere individual professionals' mental representations (Endsley, 1995; Goodwin, 1994; Nückles, 2020). In authentic classrooms, the teacher's focus of attention is inherently dynamic, arising from the teacher's active role, which requires a fundamentally different form of observation than static approaches such as video observations. In practice, teachers continuously select information and make decisions that shape not only the unfolding course of classroom events but also the opportunities for gathering situational information in subsequent cycles of situation awareness and professional vision. Capturing these in-action processes is therefore necessary to investigate the dynamic nature of these skills, which is possible with mobile eye-tracking. This study contributes by examining teacher's situation awareness and professional vision as in-action visual attention in authentic classroom settings.

2. Present study

The aim of this study is to test the Integrated model of a teacher's visual attention and investigate differences in teachers' in-the-moment gaze behavior during situation awareness and professional vision in real-life classrooms. Moreover, differences in gaze behavior during situation awareness and professional vision are explored between student teachers and experienced teachers to investigate how the skills develop through experience. The research aim is approached with the following research questions.

1. How does participants' gaze behavior differ between situation awareness and professional vision episodes?

H1. Because of the differences in teachers' actions and intentions during situation awareness and professional vision, we hypothesize the episodes to differ by gaze behavior. More specifically we hypothesize that situation awareness involves more scanning-related gaze behavior, indicated by a GRI lower than 1, whereas professional vision is characterized by longer focusing on individual pupils, indicated by a GRI higher than 1 (Lowe & Boucheix, 2016).

2. How do experienced teachers' and student teachers' gaze behavior differ during episodes of situation awareness and professional vision?

H2. Previous studies have shown that the enhanced knowledge structures enable experienced professionals to effectively maintain situation awareness compared to novices for who reasoning the situation requires more effort (Endsley, 2018). As smaller GRI refers to faster visual processing (Lowe & Boucheix, 2016), we hypothesize that experienced teachers have smaller GRI than student teachers during situation awareness. Previous research does not provide a basis for a hypothesis about the GRI difference between student teachers and experienced teachers during professional vision episodes.

3. How do experienced teachers and student teachers differ in the variation of gaze amount and duration during episodes of situation awareness and professional vision?

H3. Previous studies have shown that experienced professionals are better at interpreting the demands of the situation (Endsley, 2018; Miller, 2011) and altering their visual focus based on pupils' needs (Seidel et al., 2021). We hypothesize this to show in experienced teachers' greater variation in their gaze behavior.

3. Methods

3.1. Participants

Four experienced primary school teachers (three women and one man), four final-year student teachers from a primary school teacher program (three women and one man), and 80 fourth graders participated in the study. These teachers had 9–21 years of teaching experience and were fourth-grade class teachers in local elementary schools, teaching their respective groups for the first or second year. One experienced teacher did not usually teach mathematics during the semester when the data were collected.

Student teachers had teaching experience from three teacher training periods during their university studies, where they planned lessons and taught under the supervision of a class teacher. Additionally, they had short-term experience as substitute teachers.

None of the participants specialized in mathematics teaching beyond minor studies or in-service mathematics teaching courses. Class sizes ranged from 11 to 26 pupils. Three pupils' guardians declined participation, and for these pupils, the lesson was organized alternatively according to the school's practices during video recordings.

3.2. Ethical considerations

National research ethical guidelines for the responsible conduct of research, General Data Protection Regulation, and university guidelines for research ethics were followed throughout. The research plan was approved by the university's ethics committee. Data collection took place while each student teacher was being supervised by an experienced teacher during their training period. Participation was voluntary, and written consent was required from all participants, pupils, and their guardians. Experienced teachers received compensation for their participation. Data are stored according to ethical guidelines in data-secured web storage at the university and on two hard disks that were stored behind two locks for five years after the publication of the results of the project. The anonymity of the participants is ensured in reporting.

3.3. Data-gathering process

The data consisted of mobile eye-tracking recordings and regular video recordings of each participant's 45-min lesson. The participants were instructed to deliver a lesson on a specific fraction-related topic that would be optimally challenging for their pupils. Data were gathered from experienced teachers before the training and from student teachers at the start of their training. Before the measurements, the student teachers observed the classroom for 8 h, including mathematics lessons. Before the recording, the participants were familiarized with the equipment for about 15 min.

A Tobii Pro Glasses 2 mobile eye tracker (version 1.1.3) was used in the study. It was developed to capture gaze data in various activity and interaction situations (Tobii AB, 2016). The mobile eye tracking system comprises a head unit and a recording unit, with recordings managed via a wireless internet connection using Tobii Glasses Controller Software (x64, version 1.114.20033). The head unit includes a scene camera, eye-tracking sensors, and a microphone for voice recording. The scene camera records in 1920 × 1080 resolution at 25 frames per second, offering a wide 90° field of view in a 16:9 format, with data capture spanning 82° horizontally and 52° vertically. The eye tracker employs a video-based system to record binocular gaze data using corneal reflection and dark pupil techniques. Eye movements are detected with four sensors, capturing data at a 50 Hz sampling rate, and an automatic slippage compensation system ensures calibration accuracy during recording. Calibration was performed using the inbuilt one-point calibration system of the Tobii Glasses Controller software (Tobii AB, 2016). All the participants' mobile eye-tracking glasses were calibrated accordingly. One participant required a second calibration during the recording due to the disconnection of the wireless internet. Classrooms were well lit, featuring ceiling lights and windows along the longest wall, providing natural light.

Each recording averaged 38 min, resulting in a total of 5 h of video and eye-tracking data. The quality of the eye-tracking data was high, encompassing 78–96% of the gaze samples. Minor data loss occurred when the participants occasionally looked above or below the glasses' rim. The final 7 min of one experienced teacher's recording were excluded from the analysis due to unsuccessful calibration.

In addition, two regular video cameras were employed to obtain a comprehensive view of the classroom, extending beyond the teacher's perspective. Based on regular video data and photographs of the pupils, a seat chart was created to verify the pupils' identification. Positioned at the front and back of the classroom, the cameras collectively covered the entire classroom area, including all pupils and the teacher. Pupil seating arrangements ensured visibility in at least one of the camera views, with seats organized in pairs, groups, or rows according to the usual seating pattern.

3.4. Data analysis

Phases of the lessons when the teachers were guiding students' individual work were selected for the analysis by excluding parts of teacher-led instructions on the blackboard. These phases were selected because both situation awareness and professional vision are evidently required in these situations. During the individual work phase, pupils worked individually, in pairs, or in small groups, allowing the teacher to move around the classroom, observe, and give individual guidance. These individual work phases took 12–25 min for student teachers and 13–24 min for experienced teachers. Individual work phases consisted of one or two episodes, depending on the teacher, as some teachers took turns with individual work phases and instructions on the blackboard. The individual work phase was defined as starting when the teacher started to circulate the classroom after giving instructions for individual work and ending when the teacher announced the common teaching part to start or end the lesson.

The analysis consisted of three steps through which the episodes of situation awareness and professional vision were identified: video analysis, eye movement analysis, and the integration of these. These were followed by statistical analysis. Analysis was done with Tobii Pro Lab using the gaze filter Tobii I-VT (attention), in which the filter velocity threshold is 100°/second to catch fixations, smooth pursuit, vestibular ocular reflex, and 10–15% of saccades as indicators of attention. The filter is designed for the analysis of eye movements tracked with dynamic methods (Tobii Pro, 2019). Times of Interest analysis (TOI) was used as the analysis method because of the dynamic nature of the data used to mark dwell time on areas of interest (AOIs). The videos were gone through frame by frame to mark the start and end points of the TOI episodes. The same TOI analysis settings were used for all three analyses.

3.4.1. Video analysis

First, video analysis was conducted to identify episodes of guidance during which a teacher assisted one pupil or a small group (later guidance). Video analysis was carried out using the mobile eye tracker's video data from the teacher's perspective but without eye movements. Video analysis was done with Tobii Pro Lab using TOI analysis to mark the guidance episodes on the timeline. TOI analysis was also suitable to use for the video analysis, as it is most close to traditional video analysis and using the same analysis method and program enabled the integration of video analysis and eye movement analysis in later phases of the analysis. Guidance episodes were pupil-specific; hence, each pupil had their own TOI code, and the teacher's interaction with an individual pupil was marked as an episode. During group work, this meant that all the pupils with whom the teacher interacted were given individual but simultaneous codes. The episode was defined as the start when the teacher either started talking to the pupil or stood next to the pupil's table before talking to them. The episode stopped when the teacher either started to walk away from the pupils or stopped talking to them. Talk was the dominant definer of the starting and ending points of the episode in cases in which the teacher talked to the pupils before standing next to them or stopped talking after leaving their side. Small interruptions (such as pupils asking for permission to go to the toilet) were excluded from the analysis.

3.4.2. Analysis of the eye movement data

Second, teachers' eye movements were analyzed to identify episodes of a teacher's gaze behavior. This was done with TOI analysis from the same video material but including eye movements. Pupil-specific codes were created for each pupil; in addition, the code "Other" was used to mark the episodes when the teacher looked at something else in the classroom than the pupils or their materials. TOIs were defined by the time the teacher's attention was paid to a particular pupil AOI. A pupil's AOI included the pupil's material, face, and whole body because all kinds of gestures can include meaningful visual information about the pupil's thinking processes. In groupwork situations, TOIs were coded for all pupils if the teacher checked a group's common material or an individual pupil's material together with the pupils in the group. The guidance episodes from the video analysis were synchronized with the eye-movement analysis episodes by defining the time stamps of the starting and ending points by the nearest fixation on the pupil outside the guidance episode.

3.4.3. Integration of video and eye-movement analysis

Third, video analysis and eye movement analysis were integrated to investigate the teachers' focus of attention. Two pupil-specific TOIs were created for each pupil: situation awareness and professional vision. Situation awareness episodes included the teacher's eye movements on the specific pupil when the teacher was not instructing the pupil, that is, ongoing gaze episodes on the pupil without a concurrent guidance episode. Professional vision episodes included the teacher's eye movements on the pupil the teacher was instructing the pupil at the same time, that is, guidance and gaze episodes on the same pupil occurring at the same time. The formulation of situation awareness and professional vision episodes through the integration of video and eye-movement analysis is explained in Fig. 2, with an example of one teacher's gaze on four pupils (pseudonyms Ella, Robin, Anna, Peter, and more).

In Fig. 2, the guidance rows (dark gray) indicate the timeline when a teacher interacts with the pupil, while the gaze rows (light gray) show the teacher's eye movements toward the pupil or their material. The row "Other" shows when the teacher looks at something else in the classroom. The "Focus of Attention" row integrates video and eye movement analyses, distinguishing between situation awareness episodes—when the teacher gazes at but does not interact with a pupil—and professional vision episodes—when the teacher simultaneously interacts with and gazes at the pupil.

In the illustrated sequence, the teacher moves around the classroom, first gazing at Robin (SA) and then at a clock on the wall (Other). Next, the teacher gazes at Ella (SA), approaches her, and starts speaking to her while maintaining eye contact (PV). While guiding Ella, the teacher briefly looks at Robin (SA) before returning her gaze to Ella (PV) and then glances at the clock again (Other). Subsequently, the teacher instructs Robin but simultaneously looks at Peter (SA) before directing her gaze back to Robin (PV). After guiding Robin, the teacher continues to move around the classroom, observing the pupils by gazing at Anna (SA) and then Robin (SA).

3.4.4. Statistical analysis

In the data analysis, we used gaze duration, gaze count variables, and the GRI, which indicates the relation between gaze duration and count (Lowe & Boucheix, 2016). Hence, if GRI is over 1, it indicates longer fixation durations and lower fixation counts (in-depth processing), whereas GRI under 1 indicates shorter fixation durations and higher counts (scanning) (Lowe & Boucheix, 2016). The definition of GRI has been used unanimously in recent studies, but as a novel index, it has been interpreted and implemented in slightly different ways in statistical analysis. First, GRI was counted for each pupil because a pupil is an important information source for a teacher in a classroom situation. GRI was counted for each pupil using the following formula:

$$\text{GRI} = \frac{\text{Sum of duration of pupil-specific episodes}}{\text{Sum of amount of pupil-specific episodes}}$$

Hence, in our study, GRI describes the average duration of a single episode of a specific pupil. We used GRI as a variable to compare visual attention during situation awareness and professional vision episodes and the difference between student teachers' and experienced teachers' visual attention. Eye movement data in the statistical analyses were expressed in seconds.

The difference in experienced teachers' and student teachers' visual processing during situation awareness and professional vision was explored by comparing the GRIs with an independent samples *t*-test. A F-test (MedCalc) was used to compare student teachers' and experienced teachers' variances of duration and amount during situation awareness

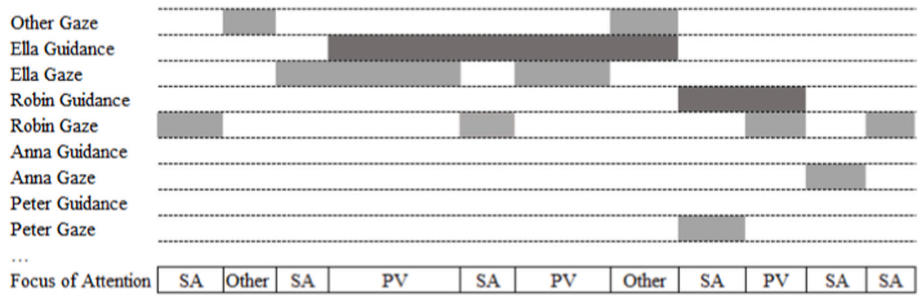

Fig. 2. Example of integration of video and eye-movement analysis to investigate teachers' focus of attention
Note: SA = situation awareness, PV = professional vision.

and professional vision.

4. Results

This study examined the Integrated Model of a Teacher's Visual Attention and investigated how teachers' in-the-moment gaze behavior varies during situation awareness and professional vision episodes in authentic classroom settings, and the differences in gaze behavior between student teachers and experienced teachers. Table 1 presents descriptive statistics pertaining to the frequency, duration, and GRI during situation awareness and professional vision episodes for both student teachers and experienced teachers.

4.1. Difference of situation awareness and professional vision by teachers' visual attention

To test the "Integrated model of teacher's visual attention", the differences in visual processing during situation awareness and professional vision were investigated by comparing all the participants' GRIs between episodes of situation awareness and professional vision. Based on Lowe and Boucheix (2016) theory, we hypothesized situation awareness to involve merely shorter but frequent scanning type of gaze towards individual pupils, indicated by a GRI lower than 1, and professional vision to involve merely longer but fewer, deepening type of gaze on individual pupils, indicated by a GRI higher than 1.

The result showed that teachers' visual attention was different during situation awareness episodes compared to professional vision episodes, which supports the hypothesis. Situation awareness episodes were characterized by shorter and more frequent gazes at pupils, which was indicated by GRI (M = 0.86) below 1. This refers to a scanning type of gaze, manifesting as rapid glances at individual pupils and capturing information from a wide visual span allowing exploratory, distributed processing (Lowe & Boucheix, 2016) that may enable the teacher to gather information about the overall classroom situation. This aligns with Endsley's (1995) definition of situation awareness as the creation and maintenance of situational understanding. In a dynamic classroom with around 20 pupils, gaze shifts are essential, since prolonged fixations on individual students could even hinder effective monitoring and the collection of critical information for tasks such as classroom management.

Conversely, professional vision episodes involved longer but fewer gazes at pupils, as evidenced by GRI (M = 9.02) higher than 1. This type of gaze can indicate deeper, more intensive processing, reflected in longer visual focus at individual pupils (Lowe & Boucheix, 2016), which may be needed to understand the pupil's learning process. This corresponds to the definition of professional vision as a pupil-centered process aimed at reasoning about pupils' understanding (Seidel & Stürmer, 2014). Longer gaze episodes are often necessary, as understanding pupils' cognitive processing requires teachers to repeatedly notice, interpret, and decide while integrating information from multiple sources such as materials and pupil's expressions.

4.2. Differences in experienced teachers' and student teachers' gaze behavior in situation awareness and professional vision

Previous studies have found differences in novices and experienced teachers visual processing. To investigate differences in student teachers and experienced teachers visual processing groups' GRIs during situation awareness episodes and professional vision episodes were compared. Aligned with the results of previous situation awareness studies we hypothesized experienced teachers to be faster in their visual processing compared to student teachers, which according to Lowe and Boucheix (2016) is manifested in experienced teachers smaller GRI. Previous research did not provide a basis for a hypothesis about the GRI difference between student teachers and experienced teachers during professional vision episodes.

The results showed that experienced teachers had faster visual processing in both situation awareness episodes and professional vision episodes, which was indicated by experienced teachers' lower GRI compared to student teachers. In situation awareness episodes an

Table 1
Descriptive statistics of student teachers' and experienced teachers' focus-of-attention episodes.

	Student teachers					Experienced teachers					All participants				
	N	Min.	Max.	M	SD	N	Min.	Max.	M	SD	N	Min.	Max.	M	SD
SA															
Count	74	1,00	41,00	9,45	7,37	78	1,00	53,00	13,18	10,78	152	1,00	53,00	11,36	9,43
Duration	74	0,39	37,37	9,37	8,75	78	0,37	50,82	10,99	10,50	152	0,37	50,82	10,20	9,69
GRI	74	0,37	2,73	0,92	0,41	78	0,36	2,35	0,80	0,34	152	0,36	2,73	0,86	0,38
PV															
Count	62	1,00	22,00	5,11	4,55	64	1,00	28,00	7,83	6,56	126	1,00	28,00	6,49	5,80
Duration	62	1,40	236,77	41,17	45,35	64	0,53	250,52	44,97	48,56	126	0,53	250,52	43,10	46,86
GRI	62	0,91	92,60	11,43	16,63	64	0,39	29,83	6,68	6,95	126	0,39	92,60	9,02	12,84

Note: SA = situation awareness, PV = professional vision, GRI= Gaze Relational Index.

independent samples *t*-test revealed a significant difference with a small effect size in GRI between student teachers (M = 0.92, SD = 0.41) and experienced teachers (M = 0.80, SD = 0.34), t(150) = 2.046, p = 0.043, d = 0.332. This result supports the hypothesis. In professional vision episodes an independent samples *t*-test revealed also a significant difference with a small effect size in GRI between student teachers (M = 11.43, SD = 16.63) and experienced teachers (M = 6.68, SD = 6.95), t (124) = 2.102, p = 0.038, d = 0.375.

Experienced teachers' faster visual processing is often interpreted as more efficient processing (Gegenfurtner, Boucheix, et al., 2020; Kosel et al., 2023), explained by their more developed knowledge structures and the ability to use them efficiently (Gegenfurtner et al., 2023). However, student teachers' slower visual processing is appropriate, as they are developing situation awareness and professional vision skills that require adapting theoretical knowledge to practice (Seidel et al., 2024). Their limited knowledge of pupils and the pedagogical context may also constrain the effective use of more advanced knowledge structures. In such settings, the cognitive load from new information is considerable, and longer visual processing reflects the effort invested in making sense of it (Wolff et al., 2020). By contrast, faster processing in student teachers might signal less concentrated and focused engagement.

4.3. Experienced teachers' and student teachers' differences in variation of count and duration in situation awareness and professional vision

Based on previous findings we hypothesized that experienced teachers have a higher variation in their visual processing, manifested by greater variance in gaze behavior during situation awareness and professional vision. The differences in variances of situation awareness and professional vision between experienced teachers and student teachers were examined using an F-test.

In situation awareness episodes there was no statistically significant difference, F(73, 77) = 1.4400, p = 0.118, between the variances of the length of experienced teachers' (SD = 10.50) and student teachers' (SD = 8.75) visual attention. However, regarding the counts of situation awareness episodes, a significant difference in variances was found between student teachers (SD = 7.37) and experienced teachers (SD = 10.78), F(73, 77) = 2.1325, p = 0.001. This may indicate that experienced teachers maintain their situation awareness by varying the amount of attention they allocate to individual pupils, while student teachers tend to distribute their attention more evenly across pupils. The result based on episode count aligns with the hypothesis, but the result regarding duration does not.

Similarly, in professional vision episodes comparisons of the variances of the durations showed that there was no difference between student teachers (SD = 45.35) and experienced teachers (SD = 48.56), F (61, 63) = 1.1466, p = 0.593. However, there was a significant difference in the variances of counts between student teachers (SD = 4.55) and experienced teachers (SD = 6.56), F = 2.0787, p = 0.005. This may indicate that experienced teachers exhibit greater variation in the number of gaze episodes on individual pupils while instructing them compared to student teachers. The findings based on episode count are consistent with the hypothesis, whereas those related to duration are not.

The variation in episode counts between student teachers and experienced teachers suggests that experienced teachers are able to shift their visual focus more flexibly, likely due to their stronger knowledge base of the situation. By contrast, the lower variance among student teachers indicates a more evenly distributed attention across the classroom, reflecting the novelty of the situation for them. The fact that differences emerge in episode counts but not in episode duration implies that both groups adjust the length of their visual focus in similar ways.

5. Discussion

5.1. Empirical implications

This study tested the "Integrated model of teacher's visual attention" by investigating differences in teachers' visual processing in situation awareness and professional vision and the differences student teachers' and experienced teachers' gaze behavior during these. The findings indicate notable differences in gaze patterns related to these aspects.

The results demonstrated that the participants' gaze behavior differed in situation awareness compared to professional vision. This supports the "Integrated model of teacher's visual attention". While attending to the overall classroom situation, teachers exhibited shorter and more frequent gazes toward pupils, which indicates a scanning type of gaze (Lowe & Boucheix, 2016) and resembles Endsley's (2000) description of situation awareness, that among other things enables classroom management (Wolff et al., 2020). In contrast, when interacting with a pupil, teachers gaze involved longer but fewer gazes at pupils, which may indicate more intense processing (Lowe & Boucheix, 2016). This is typical for the professional vision process, where a teacher is investigating individual pupil's learning by noticing specific features in a pupil's learning and reasoning it (van Es & Sherin, 2002).

The comparison of student teachers' and experienced teachers' gaze behavior showed a significant difference with a small effect size in the GRI in both situation awareness and professional vision. Experienced teachers exhibited lower GRI values, indicating faster visual processing, which is associated with greater efficiency in visual processing. Such efficiency might be due experienced teachers' well-developed mental models in situation awareness (Endsley, 2000, 2018) and situated knowledge in professional vision (Gegenfurtner et al., 2023; Nückles, 2020) that are reflected in visual processing (Gegenfurtner et al., 2011, 2023). Similar patterns have been reported in previous research, where experts' mean fixation durations were shorter than those of novices (Gegenfurtner et al., 2011). To date, only two studies have examined visual processing with GRI, both showing similar trends. Gegenfurtner, Boucheix, et al. (2020) found that medical experts processed visual information faster than novices, although the difference was not statistically significant, while Kosel et al. (2023) reported that experienced teachers in real-life classrooms demonstrated faster visual processing than novices. The results of this study support previous findings of experienced professionals' and novices' visual processing from prior research using GRI in laboratory settings.

The results of our study further indicated that experienced teachers showed greater variation in visual attention by episode counts in both situation awareness and professional vision, while no differences were found in durations. This finding aligns with previous research (e.g., Wolff et al., 2016) and with conceptualizations of skillful situation awareness, which involve effectively interpreting the demands of the situation (Endsley, 2018), and of professional vision, which entails adjusting visual focus based on pupils' needs (Seidel et al., 2021). Such processing is enabled by experienced teachers' well-developed knowledge structures. In contrast, student teachers' more evenly distributed gaze suggests that different situational elements were attended to with similar priority, which is a natural and purposeful approach in novel situations. As student teachers are still developing their situation awareness and professional vision skills, their emerging knowledge structures are likely reflected in less nuanced visual processing (Wolff et al., 2016) that is more effortful and likely imposes a greater load on working memory (Endsley, 2018). Interestingly, no group differences were found in the variation of gaze duration in situation awareness and professional vision. This may be explained by contextual or participant-related factors, which require further investigation.

The findings about the differences between student teachers and experienced teachers are in line with the descriptions of expert and novice teachers' difference reported by Berliner (1986) in his seminal article about teacher expertise; expert teachers are faster in pattern recognition and more flexible in acknowledging requirements of the situation than novices.

To our knowledge, previous studies have not explored both professional vision and situation awareness. However, some studies have recognized the effect of situation awareness on visual attention. Huang et al. (2023) professional vision study in authentic teaching situation found that expert teachers had shorter fixation durations and larger quantity of fixations than novices, which contradicts our results on professional vision but aligns with our findings on situation awareness. The authors concluded that expert teachers demonstrated superior selective attention and suggested that their gaze patterns may reflect situation awareness. Hence, even though not explicitly investigating professional vision and situation awareness, some previous studies imply the presence of both in a classroom situation. A notable feature of many professional vision studies, particularly those employing eye tracking, is the selection of the phase of the lesson, often the teacher-led start of the lesson, partly due to the substantial volume of eye-movement data generated within a single lesson (e.g., Huang et al., 2023; McIntyre et al., 2017; Kosel et al., 2023). This should be acknowledged, as the context of the selected data is likely to affect the results as different phases of the lesson are characterized by distinct pedagogical aims and purposes and visual processing is aim-guided and situated processes (Gegenfurtner et al., 2023).

5.2. Methodological implications

Eye tracking has opened possibilities for investigating teachers' focus of attention. Previous studies have revealed features of visual processing relatedness to expertise growth (Gegenfurtner et al., 2011, 2023; Wolff et al., 2016). As reported by Witt et al.'s (2024) scoping review, only some recent studies focusing on teachers' visual processing have been conducted in real classroom settings (see, e.g., Cortina et al., 2015; Huang et al., 2023; Keller et al., 2022; McIntyre et al., 2017; McIntyre & Foulsham, 2018; Pouta et al., 2020). In real classroom situations, teachers' visual attention is dynamic, as it combines with their teaching actions. Therefore, investigating teachers' visual processing in real classroom situations is important to uncover the complexity of the focus of attention processing by acknowledging that teachers actively shift their attention between situation awareness of the overall classroom situation and professional vision of individual pupils learning processes. Furthermore, our study underscores the importance of considering the lesson phase from which data are drawn when comparing results with previous research on professional vision and situation awareness, as the pedagogical purpose of each phase may influence visual processing, which is inherently situated and goal-directed (Gegenfurtner et al., 2023).

Furthermore, such dynamic settings require new approaches for analyzing eye-tracking data. Because comparisons of simply the fixation counts and durations are not possible with data collected outside the laboratory, new metrics are needed to analyze data from varying dynamic settings, such as real classrooms. Only some recent studies have tested the use of GRI with data from static settings, such as medical visualizations (Gegenfurtner, Boucheix, et al., 2020) and animation design (Lowe & Boucheix, 2016), while applying it with real-life situations, especially in an education context, is even more scarce (e.g., Kosel et al., 2023). Hence, the need to test GRI with dynamic data capturing the complexity of visual processing in real situations is addressed. This study aimed to add information on the use of metrics in such settings.

5.3. Theoretical implications

In this study, we developed a theoretical and methodological model, the "Integrated model of teacher's attention", which seeks to integrate the two simultaneous perceptual processes of situation awareness and professional vision. This integration aims to provide a more comprehensive framework for understanding the complex nature of visual processing in dynamic teaching environments. By synthetizing theories of situation awareness (Endsley, 1995, 2000) and theoretical perspectives on professional vision within educational science (Jacobs et al., 2010; Seidel & Stürmer, 2014; van Es & Sherin, 2002), our model addresses a central challenge faced by classroom teachers: how to maintain the awareness of multiple pupils while simultaneously attending to the needs of individual pupils. Our theoretical model seeks to establish a foundation for studying visual processing in dynamic contexts, a need that has grown with the increased use of mobile eye-tracking technology in educational research. Much less studies have dealt with visual attention focusing on the whole classroom situation to maintain situation awareness than professional vision focusing on individual students' learning. This does not mean that situation awareness is less important than professional vision in teaching practices. However, because of the limited capacity of simultaneous attention, it can be that focusing of visual attention on maintaining situation awareness can hinder or distract professional vision. Fast routines for maintaining situation awareness of experienced teachers may minimize its disturbing effects on professional vision. Hence, situation awareness and professional vision enable different aspect of the teaching situation to be recognized, such as classroom management and deepening to individual pupil's thinking processes. Investigating teaching situation from both aspects is potential to capture the multifaceted and intertwined nature of a teacher's visual attention in a classroom.

5.4. Limitations and considerations

The study was conducted in real classroom settings, which inherently links it to specific situational and contextual factors that also present limitations. Due to the limited sample size, the findings cannot be generalized, and the theoretical model should be tested with a larger sample. It should also be acknowledged that the context of this study was mathematics, more specifically the teaching of fractions. As professional vision and situation awareness are situated skills, the results may not be directly generalizable to other teaching contexts. Also, various situational factors influenced the teachers' actions and perceptions. Experienced teachers were familiar with the participating pupils, whereas for student teachers, the environment resembled typical training or substitute teaching where they initially lacked prior knowledge of the pupils. To address this, the student teachers engaged in mandatory observation sessions and discussions about the pupils' learning histories with the experienced teachers prior to data collection. In future studies it would be important to equalize novices' and experienced teachers' knowledge about the pupils in the classroom. However, when expert teachers start teaching a new classroom they already have a more elaborated expectation about typical classroom than novices (Berliner, 1986).

The study focuses only on teachers' visual attention in terms of gaze behavior. Mere focusing of visual attention covers only a small part of the richness of teachers' professional vision and situation awareness, leaving out empirical analysis of knowledge-based reasoning processes that are central for both professional vision and situation awareness. We agree with Louie (2018) that most of the studies applying the professional vision concept in research on teaching, including our study, are not sufficiently taking into account the social and cultural nature of Goodwin's (1994) theory. To better cover the richness of the basic concepts of the theoretical model, future studies should include methods which uncover professional knowledge underlying the features of visual attention analyzed in this study. In addition, methods should be developed to analyze the knowledge restructuring processes taking place in in professional practices on individual and socially shared levels as this study focused on the individual-level representation of the skills. Furthermore, this study focused on teachers' attention to pupils while they were working on individual tasks with rational numbers. However, our results are limited to this aspect as our analysis does not address the specific pupil actions that captured the teachers' attention.

In this study we employed a relatively new metric, the GRI, and instead of using bare fixation duration and count as in previous studies we used dwell time duration and the count of episodes based on TOI analysis because of the nature of the data. As a result, the findings are not directly comparable to previous studies using fixation-based GRI. Since GRI is sensitive to changes in gaze measurement units, we utilized it as a factor enabling statistical comparison of item means, thereby enhancing the study's robustness by reducing measurement unit effects and increasing comparability.

5.5. Conclusions

The present study contributes to the need to understand the dynamic and multifaceted nature of teachers' visual processing in authentic classrooms and how these skills develop with experience. Examining situation awareness and professional vision in authentic classroom settings with an in-action observer design is essential, as these are situated skills (Endsley, 1995; Goodwin, 1994; Nückles, 2020). In such settings, a teacher's focus of attention is inherently dynamic due to their active role, requiring a fundamentally different form of observation than the static approaches commonly used in prior professional vision research. Capturing these skills as in-action processes is necessary to understand their dynamic nature, as teachers' attention is multifaceted and shaped by the multiple, simultaneous demands of teaching situation. Furthermore, the role of situation awareness within teachers' attentional processes has yet to be investigated and to our knowledge, this is the first study to combine the examination of situation awareness and professional vision in real-life classrooms using mobile eye-tracking. Visual processing is central for attention processes and should be studied as a multilayered phenomenon, encompassing both situation awareness and professional vision, since it enables teachers to notice pupils' individual needs and guide learning effectively.

This study also highlights the importance of conducting more detailed analyses in classroom research, moving beyond treating an entire lesson or lesson phase as a single unit and instead considering the distinct pedagogical purposes and attentional demands associated with different phases. The study also emphasizes the need for using methods that are adaptive to real-life contexts, such as GRI.

Acknowledging the multitude of teachers' visual attention could also be considered in teacher education, where there would be need for training both situation awareness and professional vision. Previous studies have highlighted video-based methods' potential for enhancing visual processing. Including visual attention training on both levels to practical training, in addition to theoretical studies, could provide a potential base for enhancing situation awareness and professional vision. The results of the study can be used to better understand the premises that student teachers have for the professional training at their final stage of teacher education. Similarly, results regarding experienced teachers' visual attention skills can be acknowledged in in-service-training situations.

CRediT authorship contribution statement

Maikki Pouta: Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Erno Lehtinen:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, Conceptualization. **Tuire Palonen:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of competing interest

I have nothing to declare.

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Data availability

Due to the biometric nature of the eye tracking data, participants were assured raw data would remain confidential and would not be shared. Anonymous SPSS data can be given by request.

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