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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'

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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