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Research paper

Professional vision in the classroom: Teachers' knowledge-based reasoning explaining their visual focus of attention to students

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HIGHLIGHTS

- 50 Finnish Grade 2 teachers' professional vision in an authentic classroom setting was studied.
- A mixed-method approach of eye-tracking methodology and retrospective think-aloud interviews was used.
- Teachers' knowledge-based reasoning explained their visual focus of attention to whole class and individual students.
- Teachers' visual focus of attention can vary depending on the reasons that guide their attention.

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ABSTRACT

This study investigated Grade 2 teachers' ($N = 50$) professional vision through eye-tracking methodology and retrospective think-aloud interviews. The study examined the extent to which teachers' knowledge-based reasoning explains their visual focus of attention to whole class and individual students. We found that teachers' descriptions of students' social relations and emotions associated positively with teachers' visual focus of attention to the whole class. Teachers' descriptions of teacher-related information/elaboration and pedagogy linked negatively with teachers' visual focus of attention to individual students. The findings suggest that teachers' visual focus of attention to students may vary depending on the reasons that guide teachers' attention.

1. Introduction

Teachers' professional competence has a significant effect on students' learning (Blömeke, 2017). Since teachers have a great responsibility to pay attention to the students' skills and needs in varying classroom situations to support their learning (Hammerness et al., 2002), teachers' professional vision has been acknowledged as one of the key elements of their professional competence. Based on Goodwin's (1994) concept of professional vision, teachers' professional vision involves their ability to perceive and make sense of relevant classroom situations and actions (Berliner, 2001; Seidel & Stürmer, 2014; Sherin, 2001). Although there are some variations in the definitions of teachers' professional vision, there is a wide consensus that the concept includes two main domains: *noticing* and *knowledge-based reasoning* (e.g., Seidel & Stürmer, 2014; Sherin & van Es, 2009). Traditionally, teachers' noticing has been mapped by having teachers watch lessons video recorded from a third-person perspective (e.g., Schäfer & Seidel, 2015; Stürmer et al., 2013; van Es & Sherin, 2002, 2008). In recent years, innovative eye-tracking research methodology has been increasingly utilized to study teachers' noticing in terms of their visual focus of attention. However, there is a lack of eye-tracking studies that have also considered the second domain of teachers' professional vision, *knowledge-based reasoning*. In prior research, teachers' knowledge-based reasoning has been conceptualized and analyzed by differentiating among three domains: teachers' ability related to *description*, *explanation*, and *prediction* of the noticed classroom actions (e.g., Berliner, 2001; Borko et al., 2008; Seidel et al., 2011; Sherin & van Es, 2009). Despite teachers' important need for the knowledge-based reasoning of their

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classroom actions, teachers are rarely encouraged to spend time explaining what they know, how and why (Loughran, 2019). Since teachers' knowledge-based reasoning describes how teachers use their existing knowledge to explain and interpret the situations they notice (Blomberg et al., 2011), it is evident that the components of noticing and knowledge-based reasoning should be investigated together rather than in isolation to explain the reasons that guide teachers' noticing.

Due to the strong focus of prior research on interventional studies in which the teachers have watched and commented on video recordings of other teachers' teaching (e.g., Santagata, 2009; Sherin & van Es, 2009; Star & Strickland, 2008; Stürmer et al., 2013; van Es & Sherin, 2008), there is a need for studies that investigate teachers' own noticing and reasoning of their classroom actions hand in hand. The present mixed-method study aimed to contribute to this research gap by investigating teachers' professional vision by considering both the domains of noticing and knowledge-based reasoning. The study's goal was to investigate the extent to which teachers' knowledge-based reasoning explains their own visual focus of attention (i.e., noticing) to their whole class and individual students. In this study, the mixed-method approach was based on two discrete types of data and their analysis methods. Teachers' visual focus of attention was examined through mobile eye-tracking recordings conducted in an authentic classroom setting. Their knowledge-based reasoning was investigated by having teachers watch their own eye-tracking recording and by giving them an opportunity to comment on their visual focus of attention and classroom actions during the video watching.

1.1. Teachers' noticing investigated in terms of visual focus of attention

In a complex environment such as the classroom, in which multiple things occur simultaneously, teachers often struggle with focusing their attention equally on all the relevant events and on all the students (Seidel et al., 2011). Therefore, it is understandable that certain events or students may stand out to the teacher more than others. The concept of *noticing* was introduced by van Es and Sherin (2008) to describe the process by which teachers identified what was relevant to them while watching video recorded classroom lessons from other teachers. They defined teachers' noticing as an act of selectively attending to information in classroom situations (Schack et al., 2017; van Es & Sherin, 2008). Since then, a number of alternative conceptualisations of noticing have been suggested and researchers have continued to refine the conceptualisations through new frameworks and models utilizing both qualitative and quantitative analysis methods (Dindyal et al., 2021). Teachers' noticing has been investigated not only related to physical classroom activities but also regarding their ability to notice students and their own cognitive abilities, such as different forms of reasoning justifying and generalizing (e.g., Melhuish et al., 2020). It has been shown that especially in terms of mathematical reasoning, teachers struggle in noticing justifications and generalizations in the classroom interaction (Melhuish et al., 2020). Similar to the study of van Es and Sherin (2008), teachers' noticing, in terms of student learning and teaching, has been traditionally investigated by teachers watching video recorded examples of classroom situations and verbalizing the aspects that attract their attention (pausing the video and commenting on it) (see e.g., Borko et al., 2008; Kersting, 2008; Miller & Zhou, 2007; Santagata, 2009; Sherin & van Es, 2009; Star & Strickland, 2008). Though teachers' noticing has been typically investigated by teachers watching other people's teaching and classroom actions, some studies have suggested that teachers who watch their own teaching are able to notice more meaningful features of teaching practices and learning and can activate more contextualized knowledge about the classroom observed than when watching others' teaching (Borko et al., 2008; Goldman et al., 2007; Seidel et al., 2011).

Since noticing is characterized by the person's selective visual attention, eye-tracking methodology has begun to gain interest among researchers investigating teachers' professional vision in terms of noticing their own classroom actions. Measured through gaze, teachers' visual focus of attention (parallel terms: gaze behavior and gaze pattern; see McIntyre et al., 2019; McIntyre et al., 2017) demonstrates their ability to process visual information related to classroom situations and to their students (van den Bogert et al., 2014). Fixation data obtained in the form of quantity and time duration are the measures typically used in eye-tracking research to determine the visual focus of attention to meaningful objects, such as students and teaching materials in the classroom context (e.g., Cortina et al., 2015; Dessus et al., 2016; Haataja et al., 2019; Yamamoto & Imai-Matsumura, 2012). Prior studies have considered different teacher-related factors, such as expertise or occupational stress, and have shown that teachers distribute their visual attention unevenly among their whole class and individual students, instructional materials, and other classroom objects (e.g., Chaudhuri et al., 2021; Dessus et al., 2016; Haataja et al., 2019; McIntyre et al., 2017). Expert teachers have been found to be more capable of distributing their attention evenly across the whole class (van den Bogert et al., 2014), monitoring their classrooms more evenly and consistently (Cortina et al., 2015), and being less distracted by task-irrelevant classroom situations (McIntyre & Foulsham, 2018) compared with novice teachers. McIntyre et al. (2017) showed that, while sharing information and asking questions, expert teachers are able to focus their attention more on students, and they work more efficiently with their gaze compared with their novice colleagues. In addition, Chaudhuri et al. (2021) showed a positive association between teachers' work-related inadequacy and overall distribution of focus of attention in the classroom.

Though eye-tracking methodology enables the investigation of teachers' visual focus of attention in the classroom itself, it may only map teachers' professional vision in terms of noticing. The gaze data alone are not enough to describe teachers' professional vision, and additional data, such as interviews related to the eye-tracking recordings, are needed to explain the teachers' visual focus of attention and the rationale behind it (van den Bogert et al., 2014). Among different research fields, eye-tracking methodology has already been combined with qualitative interview data to describe the phenomenon of expertise (e.g., Gegenfurtner & Seppänen, 2013; Guan et al., 2006; Hyrskykari et al., 2008). For instance, Gegenfurtner and Seppänen (2013) conducted a mixed method study using eye-tracking data and retrospective think-aloud (RTA) interviews with medical professionals in radiology and nuclear medicine to study their professional vision. However, in elementary school classroom research, this type of mixed-method approach is rarer still, but it is much needed to map the other domain of teachers' professional vision: knowledge-based reasoning.

1.2. Teachers' knowledge-based reasoning

The second domain of teachers' professional vision, *knowledge-based reasoning* (see Fig. 1), describes the teachers' ability to reason about the classroom actions and events they have noticed (e.g., Seidel & Stürmer, 2014; Sherin & van Es, 2009). The ability to use knowledge-based reasoning provides insight into the teachers' mental knowledge representations but also into the concrete applications of the representations in their classrooms (Borko et al., 2008; Seidel & Stürmer, 2014). Based on prior research of

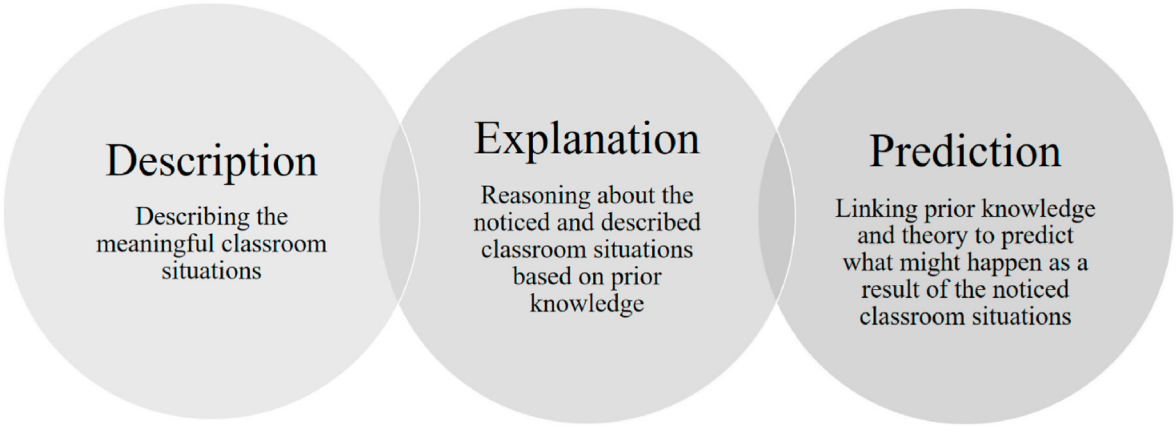

Fig. 1. Domains of teachers' knowledge-based reasoning.

observing teachers while they reflected on video recorded classroom situations, teachers' knowledge-based reasoning has been conceptualized in terms of three domains: description, explanation, and prediction (e.g., Berliner, 2001; Borko et al., 2008; Seidel et al., 2011; Sherin & van Es, 2009).

Description refers to the first domain of the teachers' knowledge-based reasoning process, in which teachers talk about their classroom observations without any extended argumentation or evaluation (Seidel et al., 2017). In other words, through description, teachers differentiate among the meaningful aspects of the noticed teaching and learning situations but do not share any further explanations for these situations (Seidel & Stürmer, 2014). Based on prior research, description has been acknowledged as an important way of utilizing professional knowledge to reason classroom situations, but it has also been suggested to be a less demanding and more typical form of knowledge-based reasoning for teachers compared with the aspects of explanation and prediction (e.g., Muhonen et al., 2021; Seidel & Stürmer, 2014). Therefore, teachers have been found to typically use description when reasoning about either their own or other people's teaching (e.g., Muhonen et al., 2021, 2022; Oser et al., 2010). On the other hand, the quality and topics of description have been suggested to vary based on the level of teachers' expertise: novice teachers have been found to describe issues predominantly concerning student and teacher characteristics, classroom management, and behavior issues, whereas expert teachers typically describe issues concerning their teaching and students' learning (Tsui, 2003).

Explanation refers to the second, higher-order domain of teachers' knowledge-based reasoning process, in which the noticed and described meaningful classroom situations are linked to prior knowledge and the teacher's understanding of teaching and learning (Seidel et al., 2011). That is, in explanation, teachers utilize what they know to reason about the noticed and described classroom situations and, further, they may classify the situations according to the components of teaching involved (Seidel & Stürmer, 2014). For example, teachers may explain that they choose certain pedagogical classroom activities to support certain areas of their students' development. In prior research, novice teachers in particular have been found to struggle with explanation in their knowledge-based reasoning compared with expert teachers (Oser et al., 2010). In addition, in-service teachers have been shown to utilize more explanation in their knowledge-based reasoning when compared with their pre-service colleagues (Gegenfurtner et al., 2020).

Finally, prediction refers to the last, and the highest-order domain of teachers' knowledge-based reasoning processes, in which the link between meaningful classroom situations and theory is utilized to predict and evaluate what might happen as a result of the noticed classroom situation (Seidel et al., 2011). For instance, a teacher may predict certain consequences of noticed classroom situations in terms of student learning. Prediction has been found to be a relatively rare type of teachers' knowledge-based reasoning (see e.g., Muhonen et al., 2021, 2022), and it is especially novice and in-service teachers who have been found to struggle with predictive reasoning compared with their more experienced colleagues (Gegenfurtner et al., 2020; Oser et al., 2010).

1.3. Aims of the study

Since teachers' professional vision is acknowledged as an important indicator of their professional competence, rigorous research is needed to map teachers' professional vision in authentic classroom settings to consider both the domains of teachers' noticing and knowledge-based reasoning. Though mobile eye-tracking has already been used to map teachers' own visual focus of attention (i.e., noticing), there is a lack of studies that have considered eye-tracking together with qualitative interviews to actually explain the teachers' visual attention in terms of their knowledge-based reasoning. Therefore, the present mixed-method study aimed to take a step further to investigate Grade 2 teachers' professional vision in an authentic classroom setting utilizing teachers' eye-tracking data and their RTA interviews in which the teachers reason their eye-tracking recordings. Furthermore, prior studies have shown that teachers of different expertise levels distribute their visual attention unevenly among their whole class, individual students, instructional materials, and other classroom objects (e.g., Chaudhuri et al., 2021; Dessus et al., 2016; Haataja et al., 2019; McIntyre et al., 2017). However, there is a lack of research that has aimed to investigate the teachers' knowledge-based reasoning to explain the reasons for teachers' varying visual focus of attention between the whole class and individual students. Due to a lack of previous mixed-method research in the classroom context and the exploratory nature of the study, we are not able to propose specific hypotheses. The research question of the present study is as follows:

> To what extent does teachers' knowledge-based reasoning (domains of description, explanation, prediction, and their sublevels) explain their visual focus of attention to the whole class and individual students?

2. Method

2.1. The Finnish educational system and teacher education

The Finnish school system is internationally known for its high quality which is based on the national curriculum, highly qualified and academic teachers, and research-based teaching (The Finnish National Agency for Education, 2018). The school system aims to offer equal opportunities to all students, basic education is free of charge, and differences among separate schools are typically small (Morgan, 2014). The Finnish educational system comprises pre-school education (one year), primary education (six years), secondary education (three years), and higher education (three years). Children enter primary education in the year they turn seven years of age, and they often have the same class teacher for several years (even during the entire six-year primary school period) who teaches most all of the subjects. Education is guided by the Finnish core curriculum for basic education (Finnish National Agency for Education, 2014) together with the local curriculums of the municipalities. However, teachers enjoy wide autonomy, and they have the flexibility to plan their own teaching based on the national and local curricula guidelines.

In her work, Niemi (2015) represents the main features of Finnish teacher education and professional development. In Finland, master's degree is the degree requirement for primary school teachers. The main focus of the five years teacher education is to combine research-based theory and practise. Therefore, teacher education includes several practical training periods that focus on planning and teaching lessons. The practical training periods offer the pre-service teacher a possibility to try out in practice everything they have learnt during their studies. In addition, research-based orientation in the pre-service education aims to support the teachers in designing school-based projects and their own development in their work. This is vital, since Finnish teachers work in a context that provides high professional autonomy and agency in their work. In-service teachers are supported with training days and short courses among their work. The new trend sees teachers as important developers among the whole school community. Also, team teaching has increased lately at Finnish elementary schools, meaning that two or more teachers work with the same group simultaneously.

2.2. Participants

The data of the present study were collected as part of a larger longitudinal research project that examined the well-being of teachers and students and the quality of teacher–student interactions in Finnish classrooms (Lerkkanen & Pakarinen, 2016-2022). The research project received ethical approval from the university's ethics committee. The data were collected in spring 2019. All the participants gave their written consent for their participation in the study, and parents gave consent for their child's participation. The participants were informed that participation in the study was completely voluntary, and they had the ability to drop out at any stage of the study.

The study sample was comprised of 50 Grade 2 teachers and students in their classrooms in central Finland. The teachers (3 male, 47 female) averaged 45.7 years of age and had an average of 18.5 years of teaching experience in primary school (minimum 0 years, maximum 40 years). All of the participating teachers held a master's degree. Out of the total of 50 teachers, 26 teachers had participated in in-service education during the past five years. Forty-four teachers reported having teaching assistant working in their classroom, on average for 7.2 h (minimum 1.5 h, maximum 23 h) per week. In total, there were 664 participating students in the 50 classrooms of the teachers (50.7% were girls). Per classroom, there were, on average, 18.8 students (minimum 5, maximum 26), and this number represents a typical primary school class size in Finland. The Grade 2 students were predominantly eight years of age. The parents' (N = 451) educational levels varied from no vocational education to a licentiate or doctorate (Mode = vocational school degree).

2.3. Procedure

2.3.1. Eye-tracking video recordings

In the first phase of the data collection process, 20-min eye-tracking video recordings were conducted in each participating teacher's classroom. The teachers wore a Tobii Pro Glasses 2 (Tobii, Danderyd, Sweden) mobile eye-tracking device during one lesson on a normal school day. The mobile eye-tracker allowed teachers to move freely, act naturally in the classroom, and conduct their usual classroom practices. The Tobii Pro Glasses 2 collected two types of data: visual data of teachers' focus of attention and the audio data. The sampling rate of the apparatus was 50 Hz (25 frames per second). The eye-tracker yielded a 1920 × 1080 pixel video, capturing 52° vertically and 82° horizontally.

Prior to the recording, two trained research assistants adjusted and calibrated the eye-tracking glasses for the teachers using a one-point calibration. At the beginning of the video recording, the research assistants confirmed the calibration and recording accuracy by asking the teachers to look at three set points on the wall. The research assistants confirmed that the gaze met the three points. The teachers were also ensured that they felt comfortable wearing the classes and moving naturally around the classroom during the recording. After 20 min of recording, the research assistants removed the equipment from the teacher.

2.3.2. Retrospective think-aloud (RTA) interviews

In the second phase of the data collection, after the eye-tracking video recordings were conducted the same day, the teachers were asked to watch their own 20-min recording. The goal of the RTA interview was to give the teachers an opportunity to recall what they were thinking during their teaching in the recording and to explain the reasons for their actions. The RTA interview was conducted privately, and only a research assistant (the same one that was responsible for the eye-tracking recording) was present with the teacher. The research assistant provided the interview instruction for the teacher at the beginning of the interview and encouraged the teacher to continue elaboration if the teacher remained silent for several minutes. All of the teachers received exactly the same instructions; no additional questions were asked while watching the video. The research assistants conducted the RTA interviews with Screencast-*O*-Matic software (Screencast-*O*-Matic, Seattle, WA, USA), which recorded both audio and visual data. At the end of the interview, the teachers were asked about their experience wearing the mobile eye-tracking device. The majority of the teachers described their experience as neutral or pleasant. They also responded that wearing the eye-tracking device had little impact on their classroom actions or teaching. A similar type of RTA interview protocol has been suggested to complement eye-tracking data in previous eye-tracking studies (e.g., Guan et al., 2006; Hyrskykari et al., 2008; Muhonen et al., 2021) as a method to collect information about the subjects' thought process, reasoning, and intentions related to their actions.

2.3.3. Teacher questionnaire

The teachers completed questionnaires in which they reported information about themselves and their classes. Since in prior research, teacher expertise and class size have been shown to link

with teachers' gaze behavior, for the present study, teacher-reported teaching experience in years and the number of students in the classroom were utilized as controlling variables in the study analysis.

2.4. Analysis strategy

2.4.1. Analysis of teachers' visual focus of attention

The teachers' visual focus of attention was analyzed based on the eye-tracking data of the 20-min eye-tracking video recordings. First, the continuous video stream was divided into fixation sequences with the Tobii Pro Analyzer software v. 1.128. The Tobii I-VT Attention Filter was used in the coding due to its ability identify fixations if either the subject (teacher) or the target (student) moves around. A fixation was defined based on the software's default, and it considered the teacher's eye gaze on a target for 60 ms or longer, a duration in which the eye is relatively steady and enables the subject's processing of visual information (van den Bogert et al., 2014).

After the Tobii Pro Analyzer had determined the fixations of the teachers' gaze, each fixation was coded based on what the teachers were focusing their visual attention on at the specific time. Separate targets in the classroom were identified as the teachers' areas of interest (AOI). Trained research assistants did the AOI coding manually by applying predetermined AOI codes (previously utilized in the studies of Chaudhuri et al., 2021 and Muhonen et al., 2020). The AOI codes for the fixations were as follows: *student* (all students who appeared during the recording were identified with their individual AOI numbers), *teacher materials* (teaching materials used by the teacher during instructions, for example, teacher's guidebook, workbook, chalkboard, projector screen, etc.), *student materials* (materials used by the students for practice, e.g., workbook, worksheets, craft items, etc.), and *other* (non-instructional objects such as windows or walls). Another trained research assistant also coded 20% of the video recordings. The level of agreement between the two coders was determined for each of the double coded lesson in terms of the coded AOIs. On average, the coders agreed on 91% of the coded AOIs per lesson (range between 86.9% and 95.2% per lesson). The intraclass correlation coefficients (ICCs) showed excellent consistency in the coding (ICC[2] = 0.995, 95% CI[0.993, 0.996]).

The present study concentrated on investigating teachers' visual focus of attention to their students (whole class and individual students) in the classroom. Therefore, only the AOI codes of the students were considered for the present analysis. The codes of other and teacher and student materials were excluded from the analysis. After coding the eye-tracking videos, variables describing teachers' visual focus of attention to students, in terms of whole class and individual students, were exported from the Tobii Pro Analyzer software for each teacher. The variables were fixation duration on the whole class (considering fixation duration on all the students in total), fixation count on the whole class (considering fixation count on all the students in total), average fixation duration per student, and average fixation count per student.

2.4.2. Analysis of teachers' knowledge-based reasoning

The RTA interview data of the teachers was analyzed in terms of their ability to knowledge-based reasoning: meaning reflections, explanations, and intentions concerning their classroom actions and visual focus of attention. First, trained research assistants transcribed the 50 RTA interview recordings, and the transcripts were timestamped to synchronize the timing with the eye-tracking recordings. The analysis was started by reading the transcripts to get an overview of the data. Next, the transcribed teacher talk was divided into analysis units. The analysis units were defined as the teachers' separate statements, which length varied from one word to complete sentences. The content of the teachers' statements could include different types of thoughts, for instance, about the teachers themselves, their students, the school as an institution in general, etc. In the present data, on average, 110.98 analysis units per RTA interview (minimum 21, maximum 349) were identified. Teachers' comments unrelated to the interview situation were excluded from the analysis and were not considered as analysis units.

Next, the researcher went through the identified analysis units again. Based on the content of the analysis unit, each unit was coded among to the domains of knowledge-based reasoning, applying the analysis framework by Muhonen et al. (2021, 2022; see Fig. 2). The analysis framework builds on the concept of teachers' knowledge-based reasoning, which in prior research (e.g., Seidel & Stürmer, 2014; Sherin & van Es, 2009) has been suggested to comprise three domains: description (identifying, differentiating, and classifying teaching and learning components); explanation (linking the observed teaching and learning components to professional knowledge); and prediction (utilizing professional knowledge to predict learning-related consequences). Furthermore, based on the framework developed by Muhonen et al. (2021, 2022), the domains of description and explanation have been found to include sub-levels that were also considered in the present analysis (see Fig. 2).

After identifying each analysis unit, the researcher made a decision whether the unit statement represented the domain of description, explanation, or prediction. Analysis units representing the knowledge-based reasoning domain of *description* were coded into two sub-levels (see Fig. 2). Within the first sub-level, the *focus* of the teacher's description was determined. The researcher determined whether the description statement described teacher action, student action, joint action (teacher and students together), teacher-related information/elaboration (teacher's beliefs, goals, strategies or feelings), student information (students' skills, characteristics, social skills or classroom behavior), general classroom information (classroom routines, activities or information about equipment and teaching/learning materials), or teacher self-reflection (noticing/realizing own actions and behavior, elaboration). Next, the same analysis unit was coded within the second description sub-level, which focused on the *content* of the teacher's description. The researcher ascertained whether the description statement described pedagogy (educational strategies, goals and actions), students' learning/performance/development (academic, behavioral or social skills and learning, physical development), classroom management/behavior (routines and actions related to classroom management, non-academic classroom behavior), or social relations/emotions (description of interaction, personal characteristics or emotions), or if the statement content was not applicable. Hence, analysis units considered as representing description were given two sub-level codes. Overall, the analysis units of description occurred the most frequently in the sample and included the largest variety of information shared by the teachers. See the following data excerpts coded as description (two sub-levels):

> "I like to use this traffic light system, it is my main strategy for behavior management" [description focus of teacher information/elaboration; description content of classroom management]

> "Though she is the youngest in the class she is most of the time ahead of the other children." [description focus of student information; description content of learning/performance/development]

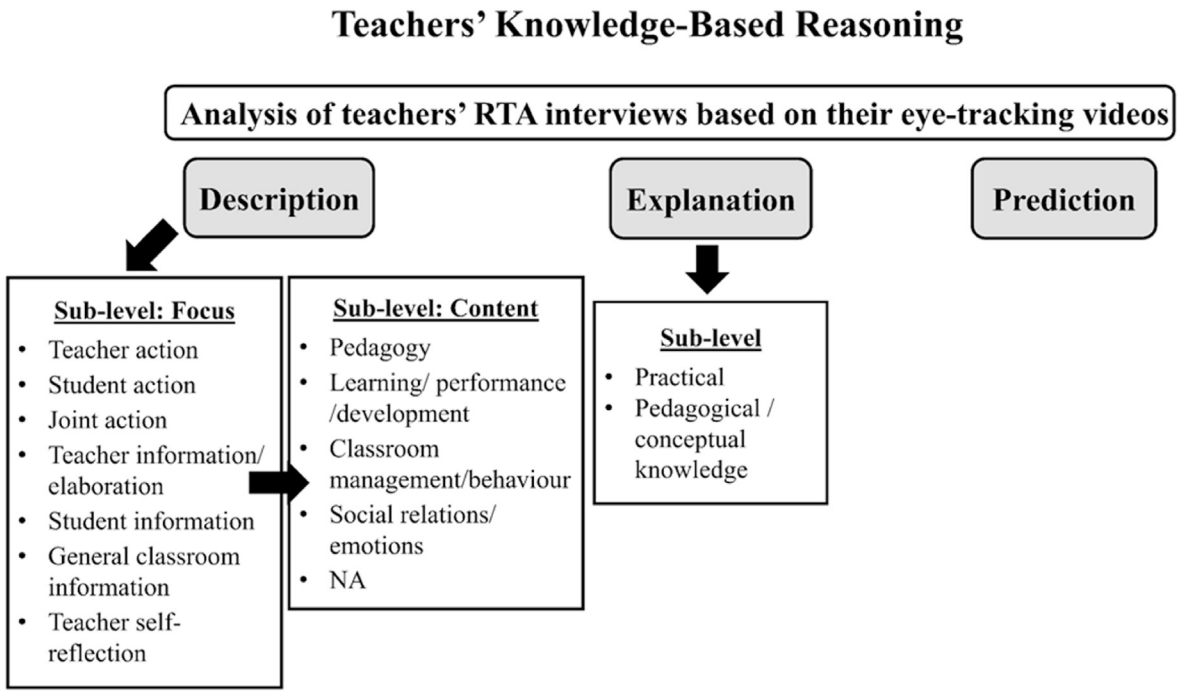

Fig. 2. Analysis of teachers' knowledge-based reasoning by Muhonen et al. (2021, 2022).

The analysis units of teacher *explanations* were coded within one sub-level. The researcher determined whether the teacher's explanatory statements included pedagogical/conceptual knowledge (explanations based on pedagogical knowledge or educational concepts) or practical knowledge (explanations based on classroom practicalities or behavioral reasons). For the analysis units representing *prediction,* there was no sub-level coding to consider. Therefore, these analysis units were only coded as teacher's prediction (goals, expectations and hopes for student performance, teaching and classroom management). See the following data excerpts coded as explanation or prediction:

> "I put much effort into this practicing phase since it is important to have the skills as automized as possible" [explanation with pedagogical/ conceptual knowledge]

> "I think within the next couple of weeks we will be ready to proceed to the next step." [prediction]

The analysis was conducted using Atlas. ti (Berlin, Germany) software. In the Appendix, descriptions of the domains and sub-levels of teachers' knowledge-based reasoning, following the coding framework by Muhonen et al. (2021, 2022), are presented along with examples of the analysis units. The first author was responsible for the analysis, but the entire research team was available for consultation and research triangulation throughout the study process. In addition, the reliability of the coding following the coding framework has been reported in previous studies of the research team (see Muhonen et al., 2021; Muhonen et al., 2022).

2.4.3. Associations between teachers' knowledge-based reasoning and visual focus of attention

In the final phase of the analysis, statistical analyses were conducted to investigate the associations between the variables of teachers' knowledge-based reasoning and visual focus of attention (to the whole class and to individual students). First, Pearson correlation analysis was conducted among the study variables. Next, based on the statistically significant findings of the correlation analysis, hierarchical regression analyses were conducted to investigate the extent to which the specific domains and sub-levels of teachers' knowledge-based reasoning explained their visual focus of attention to the whole class and individual students. In each of the hierarchical regression models, teacher's teaching experience and class size were controlled for. The analyses were conducted using IBM SPSS Statistics ver. 26 (IBM, Armonk, NY, USA).

3. Results

The aim of this study was to investigate the extent to which teachers' knowledge-based reasoning explains their visual focus of attention to their whole class and individual students. Table 1 presents descriptive information regarding the study variables of teachers' visual focus of attention and knowledge-based reasoning. Considering the teacher's visual focus of attention to all the students in the classroom during the 20-min recording, on average, the whole class received 1016.62 fixations, amounting to a total of 453.69 s of visual attention from the teacher. In terms of teachers' visual focus of attention to individual students, on average, each student received 66.12 fixations, which amounted to 30.24 s of visual attention from the teacher. The knowledge-based reasoning of the participating teachers was typically focused on the description level (M = 96.18 analysis units per teacher). Regarding the description focus, the teachers predominantly described teacher information/elaboration (M = 41.04 analysis units per teacher) and student information (M = 25.06 analysis units per teacher). Regarding the description content, the teachers' reasoning predominantly considered issues related to classroom management/ behavior (M = 31.92 analysis units per teacher) and learning/performance/development (M = 29.08 analysis units per teacher). Knowledge-based reasoning focused on explanation (M = 14.56

Table 1
Descriptive information of the study variables.

	Mean	Std. Deviation
Visual focus of attention		
Fixation duration on whole class[a]	453.69	137.96
Fixation count on whole class	1016.62	301.21
Average fixation duration per student[a]	30.24	15.66
Average fixation count per student	66.12	28.42
Knowledge-based reasoning[b]		
Description	96.18	42.25
Description focus		
Teacher action	8.98	9.268
Student action	8.76	7.33
Joint action	2.20	3.12
Teacher information/elaboration	41.04	20.17
Student information	25.06	12.16
General classroom information	5.10	3.96
Teacher self-reflection	4.74	4.94
Description content		
Pedagogy	23.84	14.74
Learning/performance/development	29.08	17.60
Classroom management/behavior	31.92	16.12
Social relations/emotions	8.48	5.31
NA	2.10	2.57
Explanation	14.56	9.27
Practical explanation	5.54	5.70
Pedagogical/conceptual explanation	9.62	6.91
Prediction	0.24	0.85

Note.
[a] Fixation duration in seconds.
[b] Numbers stand for the quantity of the analysis units.

analysis units per teacher) and reasoning ($M = 0.24$ analysis units per teacher) occurred less often in the RTA interviews of the teachers.

Next, Pearson correlation analysis showed several statistically significant associations between teachers' knowledge-based reasoning and the visual focus of attention to students (see Table 2). Considering teachers' visual focus of attention to the whole class, teachers' descriptions of social relations and emotions were associated positively with the teachers' fixation duration ($r = 0.335$, $p < .05$) and fixation count ($r = 0.379$, $p < .01$) on the whole class. In addition, teachers' prediction was negatively (albeit marginally significantly) associated with teachers' fixation duration on whole class ($r = -0.261$, $p < .08$). Considering teachers' visual focus of attention to individual students, teachers' descriptions of teacher-related information/elaboration associated negatively with teachers' average fixation duration ($r = -0.307$, $p < .05$) and average fixation count ($r = -0.301$, $p < .05$) per student. In addition, teachers' descriptions concerning pedagogy were negatively associated with teachers' average fixation duration per student ($r = -0.284$, $p < .05$) and negatively, albeit marginally significantly, with teachers' average fixation count per student ($r = -0.274$, $p < .08$). Marginally significant associations were also found between teachers' description concerning student information and average fixation duration per student ($r = -0.252$, $p < .08$) and between teachers' practical explanations and average fixation duration per student ($r = 0.278$, $p < .08$).

As the final step, hierarchical regression analyses were conducted based on the statistically significant associations found in the correlation analysis (marginally significant associations were not considered) in order to investigate the extent to which teachers' knowledge-based reasoning explains their visual focus of attention to whole class and individual students. Five hierarchical regression models were specified, in which all teacher's length of work experience and class size were included in step 1 as controlling variables for teachers' professional vision. Table 3 presents the results of the five hierarchical regression models.

Considering how teachers' knowledge-based reasoning explained their focus of attention to their whole class, the regression analyses showed no statistical significance in terms of teachers' description of social relations/emotion and fixation duration on the whole class, $F(1,44) = 1.94$, $p > .05$. However, together with work experience and class size, teachers' description of social relations/emotions explained 19.2% of the variation in teachers' fixation count on the whole class, and the regression was statistically significant, $F(1,44) = 3.48$, $p < .05$.

Table 2
Correlations among the study variables.

	Fixation duration on whole class	Fixation count on whole class	Average fixation duration per student	Average fixation count per student
Description	−0.113	−0.095	−0.221	−0.229
Description focus				
Teacher action	−0.069	−0.227	0.213	0.115
Student action	0.027	−0.004	−0.017	−0.017
Joint action	0.154	0.129	−0.032	−0.067
Teacher-related information/ elaboration	−0.163	−0.108	−0.307*	−0.301*
Student information	−0.111	−0.026	−0.252^{+}	−0.198
General classroom information	0.059	0.210	−0.239	−0.212
Teacher self-reflection	−0.037	−0.067	−0.115	−0.142
Description content				
Pedagogy	−0.215	−0.163	−0.284*	−0.274^{+}
Learning/performance/development	−0.221	−0.210	−0.221	−0.219
Classroom management/behavior	0.021	0.007	−0.079	−0.117
Social relations/emotions	0.335*	0.379**	0.103	0.146
NA	−0.094	−0.032	−0.162	−0.144
Explanation	0.003	0.003	−0.099	−0.111
Practical explanation	0.177	0.049	0.278^{+}	0.151
Pedagogical/conceptual explanation	−0.114	−0.093	−0.131	−0.110
Prediction	−.261^{+}	−0.142	−0.109	−0.069

Note. $^{+}p < .08$, $*p < .05$, $**p < .01$, $***p < .001$.

Table 3
Hierarchical regression analyses of teachers' knowledge-based reasoning explaining their visual focus of attention.

3.1. Teachers' description of social relations/emotions and fixation duration on whole class.

Variable	*B*	*SE B*	β	*t*	R^2	ΔR^2	*F*
Step 1					.000	.000	.007
Class size	420.359	4499.556	.014	.093			
Work experience	−150.367	2030.402	−.011	−.074			
Step 2					.117	.117	1.943
Class size	−766.827	4304.790	−.025	−.178			
Work experience	1044.458	1992.359	.077	.524			
Social relations/emotions	9225.001	3825.340	.354	2.412*			

3.2. Teachers' description of social relations/emotions and fixation count on whole class.

Variable	*B*	*SE B*	β	*t*	R^2	ΔR^2	*F*
Step 1					.056	.056	1.333
Class size	15.385	9.423	0.237	1.633			
Work experience	−0.467	4.252	−0.016	−0.110			
Step 2					.192	.136	3.476*
Class size	12.626	8.877	0.195	1.422			
Work experience	2.309	4.108	0.079	0.562			
Social relations/emotions	21.435	7.888	0.382	2.717**			

3.3. Teachers' description of teacher-related information/elaboration and average fixation duration student

Variable	*B*	*SE B*	β	*t*	R^2	ΔR^2	*F*
Step 1					.305	.305	9.876***
Class size	−1874.726	422.527	−0.553	−4.437***			
Work experience	9.129	190.663	0.006	0.048			
Step 2					.383	.078	9.088***
Class size	1789.684	404.379	−0.528	−4.426***			
Work experience	−124.626	190.441	−0.081	−.654			
Teacher information/elaboration	−226.295	96.264	−0.292	−2.351*			

3.4. Teachers' description of teacher-related information/elaboration and average fixation count student

Variable	*B*	*SE B*	β	*t*	R^2	ΔR^2	*F*
Step 1					.223	.223	6.469**
Class size	−2.875	0.799	−0.474	−3.597***			
Work experience	0.091	0.361	0.033	0.252			
Step 2					.295	.071	6.131***
Class size	−2.728	0.773	−0.450	−3.529***			
Work experience	−0.139	0.364	−0.051	−0.382			
Teacher information/elaboration	−0.389	0.184	−0.281	−2.112*			

3.5. Teachers' description of pedagogy and average fixation duration student

Variable	*B*	*SE B*	β	*t*	R^2	ΔR^2	*F*
Step 1					.305	.305	9.876***
Class size	−1874.726	422.527	−0.553	−4.437***			
Work experience	9.129	190.663	0.006	0.048			
Step 2					.361	.056	8.286***
Class size	1787.573	412.132	−0.527	−4.337***			
Work experience	−78.523	190.205	−0.051	−0.413			
Pedagogy	−258.438	131.646	−0.244	−1.963$^+$			

Note. $^+p < .08$, $*p < .05$, $**p < .01$, $***p < .001$.

Concerning how teachers' knowledge-based reasoning explained their focus of attention to the individual students in the classroom, more statistically significant associations were found. The hierarchical regression analysis revealed that, together with the length of work experience and class size, teachers' description of teacher-related information/elaboration explained 38.3% of the variation in teachers' fixation duration per student, $F(1,44) = 9.088$, $p < .001$. In addition, together with work experience and class size, teachers' description of teacher-related information/elaboration accounted for 29.5% of the variation in teachers' fixation count per student, $F(1,44) = 6.131$, $p < .001$). Finally, together with work experience and class size, teachers' descriptions of pedagogy-related issues accounted for 36.1% of the variation in teachers' fixation duration per student, $F(1,44) = 8.286$, $p < .001$.

4. Discussion

The present study examined teachers' professional vision in terms of the extent to which teachers' knowledge-based reasoning explains their visual focus of attention to their whole class and individual students. A mixed-method study approach was utilized to investigate Grade 2 teachers' professional vision in an authentic classroom setting through eye-tracking methodology and RTA interviews related to teachers' eye-tracking recordings. The findings

showed that, in terms of teachers' focus of attention to the whole class, a positive association with teachers' description of social relations/emotions was found. Moreover, the description of social relations/emotions explained the variation in teachers' visual focus of attention in terms of fixation count. Regarding teachers' visual focus of attention to individual students, negative relations were found with teachers' descriptions of teacher-related information/elaboration and pedagogy. In addition, the description of teacher-related information/elaboration and pedagogy explained the variation in teachers' visual focus of attention to individual students in terms of fixation duration and count.

Regarding teachers' visual focus of attention to the whole class, the results showed that the teachers' description of social relations/emotions explained the variation in their visual focus of attention in terms of fixation count. The results may indicate that paying attention to social relations in the classroom requires teachers to invest a higher amount of visual attention among several students. Prior studies have shown that teachers often distribute their visual attention unevenly among their students, and some students receive more teacher's attention than others (e.g., Dessus et al., 2016; Haataja et al., 2019). However, prior studies have been predominantly conducted with a focus on teachers' expertise and/or students' performance. The findings of the present study indicate that paying attention to social relations and emotions may require teachers to distribute their attention among all the students in the classroom to be able to observe the complex social web between the students and the teacher. Since, in prior research, teachers' professional vision, and especially knowledge-based reasoning, has been predominantly investigated by having teachers watch other people's teaching and classroom interactions (e.g., Santagata, 2009; Sherin & van Es, 2009; Star & Strickland, 2008; Stürmer et al., 2013), observing and reasoning about the social relations from the objective study setting may have been more challenging for the teachers. However, it has been suggested that teachers who watch their own teaching are able to notice more meaningful classroom features and can activate contextualized knowledge about the classroom observed (Borko et al., 2008; Goldman, 2007; Seidel et al., 2011). The findings of the present study concur with these suggestions. In the present study, the teachers reasoned the classroom actions of their own class, which they knew very well. Therefore, they may have been more capable of focusing on more subjective aspects in their reasoning, such as describing the social relations and emotions of their class.

Regarding teachers' visual focus of attention to individual students, the description of teacher-related information/elaboration (description focus) and pedagogy (description content) linked negatively with teachers' visual focus of attention in terms of fixation duration and count. Since the analysis units representing the knowledge-based reasoning domain of description were coded into two sub-levels, focus and content, the focus of teacher-related information/elaboration often occurred together with the content of pedagogy. Therefore, we see that it is important to discuss these findings together. As suggested by Seidel et al. (2011), the classroom is a complex environment in which multiple things occur simultaneously, which is why teachers often face challenges in focusing their attention on all the relevant events, students, and teaching. The teachers simply do not have enough time and resources to focus on everything that is happening in their classrooms. The findings of the present study may indicate that when teachers are more focused on their teaching and pedagogical aspects, they pay less attention to individual students in the classroom. In their study, McIntyre et al. (2017) showed that during information sharing and asking questions, expert teachers were more capable of focusing their visual attention on students, compared with their novice colleagues. Though their study approach was different and focused more on comparing expert and novice teachers, their findings concur with the findings of the present study, suggesting that focusing on both effective instructional practices and gaze on students can be challenging for teachers. However, in the present study, the teachers' visual focus of attention only to students was examined. In future research, teachers' attention to teaching materials and other classroom objects should also be examined in order to map teachers' professional vision more rigorously during teaching.

It is also worth noting that the knowledge-based reasoning domains of explanation and prediction occurred relatively seldom in the sample, and fewer associations regarding them were found. Concurring with prior research on teachers' knowledge-based reasoning (e.g., Muhonen et al., 2021, 2022), the reasoning of the teachers in the present study was predominantly focused on description. In prior literature, the domains of explanation and prediction have been considered to be more elaborative, complex, and integrated knowledge structures when compared with description (Putnam & Borko, 2000; Seidel & Stürmer, 2014). Hence, providing explanatory and predictive elaboration regarding their eye-tracking videos may require more sophisticated professional knowledge and effort from the teachers than providing description. Nevertheless, some marginally significant associations in terms of explanation and prediction were found. The findings suggest a marginally significant negative association between teachers' prediction and visual focus of attention to the whole class. In addition, teachers' practical explanations were found to associate positively, albeit marginally significantly, with their visual focus of attention to individual students. However, based on these marginally significant associations, which may be due to the small sample size of the study, no strong interpretations can be made regarding the relationships among teachers' explanation, prediction, and visual focus of attention. To investigate these associations further, in the future, more research with larger sample sizes is needed.

4.1. Implications, limitations, and future directions

The present study has important theoretical, methodological, and practical implications. In terms of the theoretical and methodological implications in the field of education, the present mixed-method study is among the very first to utilize mobile eye-tracking combined with qualitative interview data to describe teachers' professional vision. Although, among different research fields, eye-tracking has already been utilized together with qualitative interview data to investigate the phenomenon of expertise (e.g., Gegenfurtner & Seppänen, 2013), this type of mixed-method research is still rare in authentic classroom research. Since, in prior research, teachers' professional vision has been typically studied through interventions and special training programs, in which the teachers have watched and commented on video recordings of others' teaching (e.g., Santagata, 2009; Sherin & van Es, 2009; Star & Strickland, 2008; Stürmer et al., 2013), the present exploratory study adds to this research. With the help of mobile eye-tracking data, recorded in an authentic classroom setting, and having the teachers watch and reason their own eye-tracking recording privately, the present study provides more detailed and

profound information regarding teachers' professional vision. The present study is among the first to explain teachers' visual focus of attention based on their own knowledge-based reasoning.

Regarding the practical implications of the study, the findings showed that paying attention to social relations in the classroom requires teachers to invest a higher amount of visual attention among the whole class. On the other hand, when teachers are more focused on their teaching and pedagogical aspects, they pay less attention to individual students in the classroom. Therefore, we suggest that it is important that teachers receive information and become aware of the fact that their visual focus of attention to whole class and individual students may vary based on the reasons that guide their attention (e.g., pedagogy or social relations). In order to direct their visual focus of attention efficiently and consciously, teachers should become aware of the aspects that can guide their attention in the classroom, but also be able to verbalize, reason about, and reflect on these aspects. Therefore, there should be a stronger focus on training teachers' professional vision, both in the pre-service and in-service training phases. As in the present study, together with the RTA interviews, the eye-tracking methodology could be used in the teacher training to demonstrate to teachers their visual focus of attention. With the help of eye-tracking recording and its related reasoning, both in-service and pre-service teachers could gain knowledge of their own visual focus of attention in the classroom and have practical training on how to reflect on it. Furthermore, as the findings of the present study suggest, teachers predominantly utilize description in their knowledge-based reasoning. In order to increase teachers' awareness and knowledge regarding their professional vision, special attention should be paid to training their knowledge-based reasoning in terms of explanation and prediction.

It is also important to acknowledge that the study has certain limitations to be considered when interpreting the results. First, the number of participating teachers ($N = 50$) was relatively small for the statistical analyses. Therefore, in future research, the study findings should be replicated with a larger sample of participating teachers. Second, the present study was cross-sectional. Consequently, strong causal inferences should be avoided when discussing the results. It is also worth noting that though in the analysis strategy the teachers' knowledge-based reasoning is expected to explain the teachers' visual focus of attention, the actual RTA interviews were conducted after the eye-tracking recordings. This was done for the purpose of the teachers being able to retrospectively explain their visual focus of attention and actions that happened during the eye-tracking recording. Third, the subject and classroom activities within the teachers' eye-tracking recordings varied based on the regular school day schedule of the class. It should be acknowledged that the subject or classroom activities of the lesson can have an impact on teachers' use of professional vision. Fourth, during the RTA interviews, the same instructions were provided to all the teachers. The research assistants followed a strict interview protocol, and therefore, no follow-up questions related to teachers' comments were asked. In the future, some clarifying or expanding follow-up questioning could be asked to encourage broader teacher elaboration. In prior research, these types of teachers' interviews have been analyzed and coded utilizing different coding frameworks to study teachers' knowledge-based reasoning. In future research, different coding approaches, such as the coding scheme suggested by Gegenfurtner et al. (2020) should be utilized to validate the findings and to explore the data further. Fifth, it is important to acknowledge, that though majority of the teachers described their eye-tracking experience neutral or pleasant, the unfamiliar eye-tracking situation may have had an impact on the teachers' classroom actions and choices either consciously or unconsciously. Finally, the study was conducted in Finland, a Nordic country with a relatively small population and little cultural variation. Since the Finnish educational system differs from many other international educational systems, in the future, further investigation including other countries and more cultural variation is needed to validate the results.

5. Conclusions

To conclude, the present exploratory study contributes to the prior research on teachers' professional vision by utilizing a mixed-method approach of teachers' eye-tracking and RTA interviews. The findings are of great importance because there is a lack of studies that have mapped teachers' professional vision in terms of both noticing and knowledge-based reasoning of their own actions. The findings of the present study indicate that teachers' visual focus of attention to whole class and individual students may vary depending on the reasons that guide teachers' attention. Paying attention to the social relations and emotions of the class may require teachers to invest a greater amount of visual attention among the whole class. On the other hand, while focusing on teaching and pedagogy-related aspects, teachers might direct less visual focus of attention to the individual students in the classroom. Based on the study findings, we suggest that it is important that teachers become aware of the diverse aspects that may guide their visual focus of attention in the classroom. In order to direct their visual focus of attention more consciously and efficiently and to be able to reason the aspects that guide their attention, teachers require knowledge and practical training in both the pre-service and in-service phases of their career.

Credit author statement

Heli Muhonen: Conceptualization, Methodology, Writing – original draft, Eija Pakarinen: Writing- Reviewing and Editing, Project administration, Marja-Kristiina Lerkkanen: Writing-Reviewing and Editing, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix. Examples of analysis units representing the domains and sub-levels of teachers' knowledge-based reasoning by Muhonen et al. (2021, 2022)

Domains of Knowledge-Based Reasoning	
Description	
Focus of Description	
Teacher action	"Here, I am going to get the drawing supplies."
Student action	"She is just running around the classroom."
Joint action	"Now, we are just reading in turns in our story circle."
Teacher information/elaboration (goals, strategies, beliefs, feelings)	"I believe that it all begins with really knowing your students and building a strong relationship with them."
Student information (characteristics, behavior, skills, social relations)	"He is such a character, so lively and ready for anything."
General classroom information (routines, classroom/school activities and tasks, information about equipment)	"It's great that we have a teaching assistant available almost throughout the day."
Teacher self-reflection (realizing and noticing one's behavior, elaboration)	"It seems like I look at this side of the classroom and those children a lot less. I was not aware of that …"
Content of Description	
Pedagogy (educational and pedagogical actions, goals, and strategies)	"I try to keep the instruction part clear and short for us to move to independent work."
Learning/performance/development (academic performance, learning social or behavioral skills, physical development [age])	"They have really progressed a lot with their writing, the result of active practise."
Classroom management/behavior	"I usually give them 2 min to tidy their desks and calm down for the next activity."
Social relations/emotions	"I have never seen these two girls in this kind of argument, they are best friends."
NA (not applicable comments)	"I put some spring decorations here in the classroom last night."
Explanation	
Pedagogical/conceptual knowledge (explanations for actions or thoughts based on educational concepts or pedagogical knowledge)	"I let them decide this because I want to support their independence and initiative."
Practical (explanations for actions or thoughts based on practical explanations and behavioral reasons)	"I have the books here, so it is nice and quick for the students to collect them in the beginning of the lesson."
Prediction	
(expectations, goals and hopes for student learning and for more general classroom actions and teaching)	"I have a feeling that these guys will go far if we continue practicing as hard as we have during this semester."

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