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

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

KEYWORDS

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

1 Introduction

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

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

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

1.1 Expert teachers' professional vision of classroom management

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3 Materials and methods

3.1 Sample

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

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

3.2 Materials and procedure

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

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

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

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

3.3 Data analysis

3.3.1 Eye-tracking data analysis

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

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

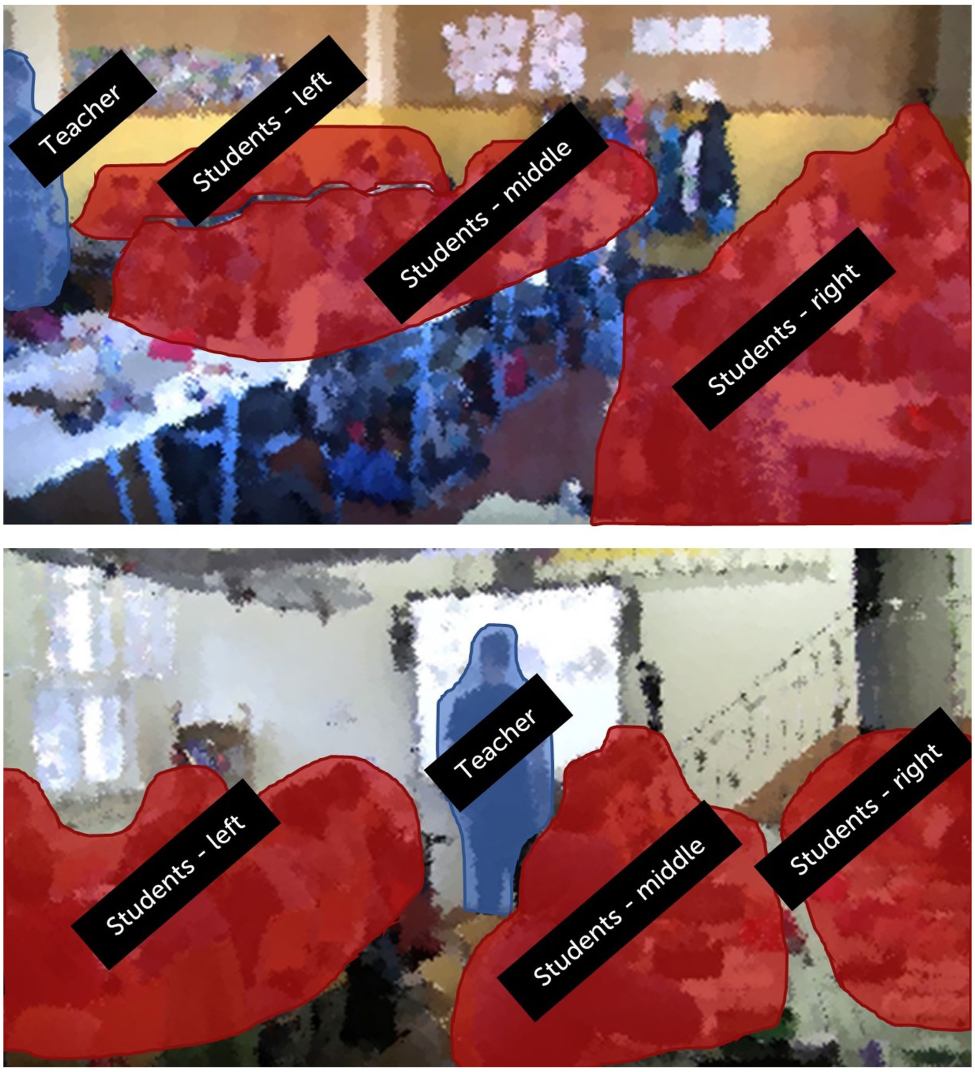

FIGURE 1
Areas of interest in the whole-group (top) and the partner work setting (bottom).

3.3.2 Content analysis of the think-aloud data

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

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

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

TABLE 1 Example of coded data from one expert teacher.

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

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

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

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

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

3.3.3 Epistemic network analysis of the think-aloud data

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

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

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

4 Results

4.1 Expert teachers' visual attention when observing the classroom scenes

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

4.2 Expert teachers' noticing of classroom management events

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

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

4.3 Expert teachers' knowledge-based reasoning

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

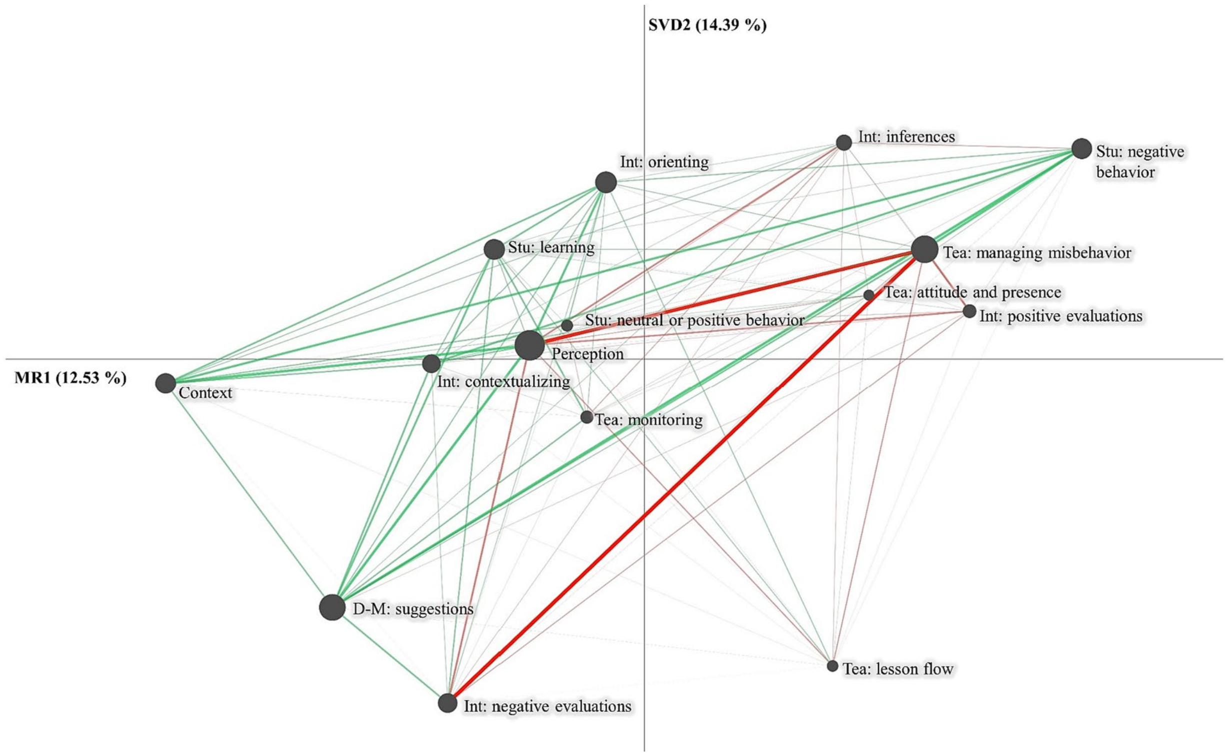

FIGURE 2
Epistemic subtraction networks of differences between biology expert teachers' (green) and mathematics expert teachers' (red) TPVCM for the whole-group instruction setting. Black dots indicate nodes: bigger dots indicate more frequent codes; colored lines indicate differences of the strengths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

5 Discussion and conclusions

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

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

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

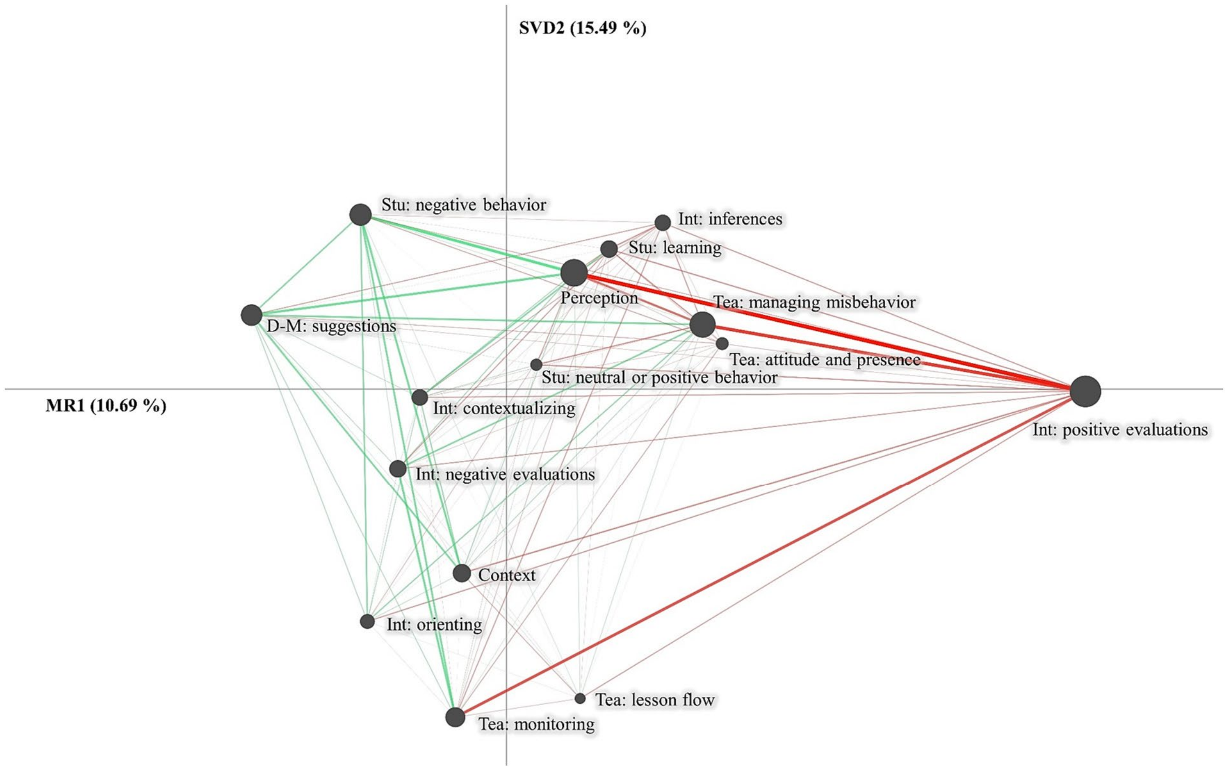

FIGURE 3
Epistemic subtraction networks of differences between biology expert teachers' (green) and mathematics expert teachers' (red) TPVCM for the partner work setting. Black dots indicate nodes, bigger dots indicate more frequent codes; colored lines indicate differences of the strengths of connections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

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

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

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

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

5.2 Limitations

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

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

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

5.3 Conclusions

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

Data availability statement

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

Ethics statement

The studies involving humans were approved by the Senate Department for Education, Youth and Family for Berlin, Germany. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

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

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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

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