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Research article

Subtle direction or collegial support?
A mathematics teacher's visual attention to teaching partners

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Abstract: Co-teaching can benefit learning and well-being of all students in inclusive classrooms. In Finland, co-teaching is a pivotal method of support for students with special needs in learning mathematics, but the outcomes are dependent on the quality of co-teaching. However, little is known about how effective co-teaching is situationally constructed in classrooms. The aim of this study was to pilot the approach to investigate the patterns of teaching partners' interaction in mathematics education. This mixed-method case study charts visual attention between teaching partners in mathematics education. The data was collected with mobile eye tracking in four mathematics lessons with the same mathematics teacher and his seventh-grade students. This study provides introductory information on how a mathematics teacher attends to the co-teaching partners during instruction with short glances during mathematics teacher's instruction, and long dwells when listening to the teaching partner. Our findings indicate that teacher's attention to the teaching partners was relative to the pedagogical and interactional situations and often took place during moments with emotional triggers to the teacher.

Keywords: co-teaching, eye tracking, inclusive education, mathematics education, mixed-method research, teacher emotions

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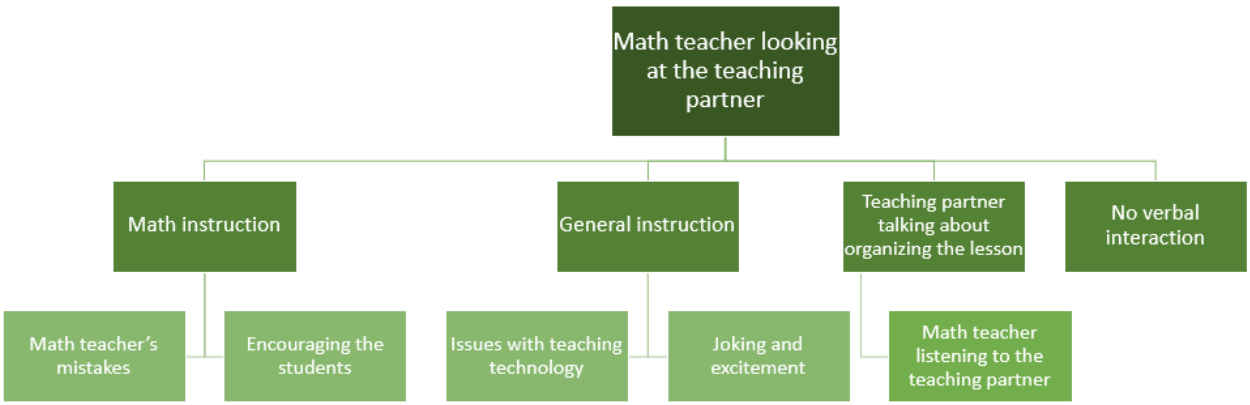

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1 Introduction

Co-teaching is a central part of inclusive mathematics education (Iacono et al., 2023). Understanding the role of situational social aspects in teaching mathematics is crucial for improving the outcomes of the instruction (Olive et al., 2022). Teachers play a pivotal role in supporting students' mathematical learning through every-day classroom interactions, and positive classroom interaction can lead to higher academic achievement (Järvenoja et al., 2020; Zeinstra et al., 2023). The teachers also face challenges in the classrooms. The Finnish National Agency for Education (Finnish National Agency for Education, 2014) introduces co-teaching and special needs assistants as central pedagogical solutions for supporting students who are struggling with mathematics learning in inclusive classrooms. However, collaboration of teaching partners requires not only pedagogical and mathematical but also socio-emotional skills (Jardí et al., 2022; Muehlbacher et al., 2022) and attention to interpersonal relationships of the teaching partners (Sundqvist et al., 2023).The quality of the collaboration among teaching partners affects its influence on teachers' professional development (Lloyd et al., 2020). Recent research has acknowledged the need for further understanding on the varying patterns of teacher collaboration and their impact on effective instruction (Maag Merki et al., 2022).

Teaching is a complex professional practice, in which continuous direction of attention to relevant visual information is an essential skill (Chi, 2006). Understanding of teacher-student eye-contact interaction has recently started to build up. Teachers' eye contact interaction with students relates to their subtle behaviors of friendliness and control: the teachers can aim to convey immediacy through dyadic eye contact, or to direct the students' work with supervising attention (Haataja et al., 2021). However, little is known about how the teaching partners use nonverbal interaction in their work in the classrooms. The patterns and characteristics of effective use of the in-situ co-teaching practices for social and academic benefit of the students remain unclear for researchers, practicing educators, and policy makers (Carty & Farrell, 2018; Iacono et al., 2023; Spörer et al., 2021). This study is a part of a Nordic QUINT research collaboration (NordForsk, 87663), and the first step to provide in situ information about nonverbal teaching-partner interaction that may either enhance or hinder effective co-teaching. The aim of this study is to explore visual attention between teaching partners to pilot the approach to investigate the patterns of teaching partners' interaction in mathematics education.

2 Theoretical background

2.1 Collaboration between subject teachers, special needs teachers, and special needs assistants

The Finnish National Core Curriculum (Finnish National Agency for Education, 2014) states that subject teachers, special needs teachers, and special needs assistants are to

collaborate for the best support of all students, and especially those with special needs. The curriculum mentions social and emotional needs, issues with language learning, and mathematical difficulties as justifications for the students to receive special support, for example in a form of co-teaching. Co-teaching and collaboration with special needs assistants are seen as significant resource and pedagogical methods of supporting students with and without special needs. The National Curriculum highlights the importance of co-planning the classroom actions with all the adults working with the students. Research acknowledges also the need for joint planning and pedagogical reflections between teachers and special needs assistants (Jardí et al., 2022). Optimally, joint planning and reflection can help the teachers in facilitating the students' mathematics learning and decrease their worries about classroom management, that is, directing students' behavior and engagement (Hodgson & Wilkie, 2022). In this paper, we refer to these kind of pedagogical actions as general instructions.

Students tend to prefer co-teaching over solo teaching (Iacono et al., 2023; King-Sears & Strogilos, 2020). The presence of two adults in the classroom is especially important for students with special needs (Sharma & Salend, 2016; Spörer et al., 2021), and these students have been found to communicate more with the special needs assistant (Webster & Blatchford, 2013) or special needs teacher (Spörer et al., 2021) than with the teacher who has the leading role in the instruction. Thus, special needs teachers and assistants may have an important role in providing scaffolding, which refers to situated, individual or group-level support to the students in their pursuits to achieve the learning goals (Van De Pol et al., 2010). Sixth grade students have been found to experience the assisting special needs teacher as the person helping them and ensuring their correct understanding of mathematical contents (King-Sears & Strogilos, 2020).

The most used approach of structuring co-teaching in compulsory school is the one teaches, one assists-method. This means that as the special needs teacher works among the students helping them to reach the learning objectives (King-Sears & Strogilos, 2020; Spörer et al., 2021), the subject (mathematics) teacher is in charge of the classroom management and providing the whole-class mathematics instruction. The whole-class mathematics instruction aims at eliciting students' mathematical thinking through posing questions and leading discussion among the mathematics teacher and the class of students (Orr & Bieda, 2023).

Finnish subject teachers are found to emphasize subject matters in teacher collaboration, whereas special needs teachers focus on social and cognitive needs of individual students (Paju et al., 2022). These predefined roles can hinder the collaboration and cause experiences of inequality between the teaching partners, especially between special needs teachers and subject teachers (Sundqvist et al., 2023). The role of special needs assistants varies from following one student throughout the day to shuttling between various classes lesson to lesson. Often, the relation between individual teachers and special needs assistants are not pre-planned outside the official requirements of teacher being responsible of the instruction and assessment, and it depends on the

individuals whether the teachers and special needs assistants practice joint planning or reflections on the classroom practices (Jardí et al., 2022; Opoku et al., 2024).

Difficulties in teaching partners' collaboration may hinder the efficacy of classroom practices (Iacono et al., 2023). Engagement in collaboration and shared understanding of teacher practices have been found to support professional development in co-teaching (Lloyd et al., 2020) and teacher-assistant collaboration (Jardí et al., 2022). The one teaches, one assists-method requires attention to interaction between the teaching partners during the lessons (Carty & Farrell, 2018). Importantly, research has suggested the inefficacy of co-teaching for student learning results from issues in the actual situational utilization of co-teaching (Cook et al., 2017). A recent interview study with middle school teachers found that sharing the positive and negative emotions with the teaching partner improves the teacher collaboration and well-being (Muehlbacher et al., 2022). On the contrary, Finnish teachers have reported ignorance towards the teaching partner during the lessons causing feelings of lack of mutual respect (Pesonen et al., 2021).

With novel information on the situational interaction between the teaching partners in the classroom, practicing teachers can be provided with help in improving their teaching practices, and the educational research field can reach understanding on a completely uncharted aspect of teacher profession (Määttä et al., 2021). To capture these micro-level dynamics in classroom collaboration, previous research suggests the approach of single-case design (Cook et al., 2017). Technological advances allow us to measure teachers' in-situ behavior in the classroom with high validity and accuracy.

2.2 Eye-contact interaction in mathematics classrooms

Even though most educational eye-tracking research is conducted in static laboratory settings (Strohmaier et al., 2020), the body of understanding of teachers' visual attention in mathematics classrooms has started to build up. Humans direct their visual attention in the environment to targets (i.e., areas of interest) that include relevant information for performing the task at hand (Hannula et al., 2022). In eye contact interaction, human gaze has two purposes: to collect and signal information (Jarick & Kingstone, 2015). McIntyre and colleagues (McIntyre et al., 2019, 2020) have conceptualized teacher visual attention through the main categories of the teachers' classroom tasks: lecturing and asking or answering questions. Thus, in the context of classroom interaction, the purpose of the teacher gaze towards students has been categorized into Attentional and Communicative attention. When the teacher communicates information for the students by lecturing or instructing them, the gaze is communicational, that is, it provides students with information on the teachers' priorities and intentions. While asking or answering to questions, the teachers attend to the students with attentional gaze to receive information for the situational needs of instructional interaction (McIntyre et al., 2019; 2020). In addition to these phases of verbal instructional interaction between the teachers and students, the lessons include moments of silence, when the teachers can, for example, roam in the classroom and monitor the students to collect information for situational pedagogical decisions

(Haataja, Garcia Moreno-Esteva, et al., 2019).

Teachers' beliefs and experiences direct their visual attention during the classroom interaction (McIntyre & Foulsham, 2018). Regardless of the content of the instructional interaction, most of the teachers' visual attention is directed to the students (Haataja, Garcia Moreno-Esteva, et al., 2019; Määttä et al., 2021). The second key area of interest for teachers are the teaching materials (Praetorius et al., 2017). Expert teachers pay a lot of attention to students (McIntyre et al., 2019), especially the ones who struggle with focusing on studying (Yamamoto & Imai-Matsumura, 2013). Teachers seek for immediate contact with their students when encouraging them emotionally, and students tend to join this eye contact when teacher behaviors are friendly (Haataja, Toivanen, et al., 2019; Haataja et al., 2021). Timely teacher attention and nonverbal interaction can enhance students' situational and long-term learning outcomes in mathematics (Haataja et al., 2024; Wakefield et al., 2018), but further knowledge is needed on the distribution of the attention when there are more than one teachers in the classroom.

Deciding on how to distribute the attention in the classroom is at the core of the momentary processes of teacher profession (Dessus et al., 2016). Therefore, the proportion of teacher's visual attention to a certain area of interest, such as an individual person in the classroom, can be interpreted to reflect on their pedagogical priorities (McIntyre et al., 2019). Teacher's professional goals are not solely oriented to their students and classroom activities, but also to collegial collaboration (Burić & Frenzel, 2019). Communication between teaching partners is also important for the successful and effective instruction (Iacono et al., 2023), but teacher-teacher visual attention and eye contact interaction have remained unexamined in the research field. Teacher's visual attention is found to be intentionally directed to the most relevant areas of interest, rather than reactive to sudden external stimuli (McIntyre & Foulsham, 2018). Therefore, we propose widening the research scope of teachers' visual attention to the context of joint teaching of two teachers and assume that attention between the teaching partners can inform us about their nonverbal interaction and shared intentions.

2.3 Emotional triggers in instruction interaction

Teachers experience various situational emotions in instruction interaction, caused by emotional triggers, that is, incidents in the classroom that stimulate emotions in teachers (Bower & Carroll, 2017). The emotions, that the teachers experience, are of course individual and depend on their self-efficacy (Burić & Frenzel, 2019), wellbeing (Parker et al., 2012), and the context of the teaching (Bower & Carroll, 2017). Teacher emotions can vary across instructional contexts and individual teachers may experience very distinct emotions in similar contexts (Uzuntiryaki-Kondakci et al., 2022). Even though the emotions themselves are inner arousals, emotional triggers causing these emotions can be observed from video data (Bower & Carroll, 2017; Uzuntiryaki-Kondakci et al., 2022)

Emotions are usually categorized by their valence (Bower & Carroll, 2017; Pekrun, 2006). Often the negative emotional triggers relate to student behavior and struggles, as

the teachers may feel stress for helping all students to reach their potential in learning (Parker et al., 2012). Observing students' success in learning or engagement in peer collaboration, but also the teachers' own success in teaching mathematics tends to trigger positive emotions (Bower & Carroll, 2017; Jenßen, 2021). In addition to the perceived classroom incidents, also out-of-classroom factors, such as awareness of negative collegial relationships can trigger negative emotions in teachers (Burić & Frenzel, 2019).

A study with eleven Australian secondary school teachers found that whereas students' behavior and workload triggered negative situational emotions among participants, colleagues triggered positive emotions. Connectedness and collaboration with other teachers improved especially the teachers' sense of being organized, calm, satisfied, and relaxed (Bower & Carroll, 2017). A Croatian qualitative study indicated that unfairness and uncooperativeness of colleagues triggered anger among secondary school teachers (Burić & Frenzel, 2019). A competitive teaching environment can also increase the teacher's tendency to avoid failures, which again negatively affects their well-being in work (Parker et al., 2012). In situational classroom interaction, stressful incidents are found to negatively affect teacher's visual attention (Chaudhuri et al., 2022). In the context of mathematics, the teacher's own mathematics skills and their conceptions of others being aware of these skills can trigger emotions of pride or shame, which can affect their behaviors towards the students (Jenßen, 2021).

3 Research questions

Mobile eye tracking provides access to first-hand evidence on the direction of visual attention and nonverbal interaction, as it captures the dimensions of the dynamic, complex, and reciprocal interactions in teaching processes (Dindar et al., 2020; Hannula et al., 2022). When examining micro-level interactions invisible to traditional research methods, multimodal data sources play a crucial role (Haataja, 2021; Järvelä et al., 2021)

Studies investigating teachers' visual attention in authentic school environments are scarce, and especially situational nonverbal interaction between teaching partners has remained an unexplored field. This study explores teacher's visual attention between teaching partners in lower secondary mathematics education. In this study, we are piloting our research to investigate how teaching partners communicate with each other in mathematics class. Our research questions were:

1. How often does a mathematics teacher direct visual attention to his teaching partners in seventh grade mathematics lessons?
2. How does the visual attention to the teaching partner differ with respect to teacher's gaze purpose, pedagogical situation, and gaze duration?
3. What kind of mathematics teacher's visual attention to the teaching partners takes place during emotional triggers in the instruction interaction?

4 Methods

4.1 Participants

This is a mixed-method single case study with one Finnish mathematics teacher, special needs teacher, special needs assistant and their seventh-grade class. We collected the data in February 2020 during four co-taught mathematics lessons (75 min each). In every lesson, the same mathematics teacher was in charge of the instruction. Additionally, on the first and fourth lessons, a special needs teacher was present in the classroom, and on the second and third lessons there was a special needs assistant who was also a mathematics-teacher student at the time. The data is as a part of the LISA Nordic research data (Klette, 2022) in the QUINT research project (NordForsk, 87663). All the participating adults and students consented to participate, and the students' caregivers were informed on the study. The use of mobile eye tracking in this kind of research setting was reviewed and approved by the University of Helsinki Ethical Review Board in the Social Sciences. The authors were not personally familiar with the participant teachers which enhances avoiding biases in the observations.

The mathematics teacher was a qualified mathematics teacher with seven years of teaching experience at the time of the data collection. The special needs teacher was qualified as an elementary school and special needs teacher and had 26 years of teaching experience. She did not specialize in mathematics but had participated in professional development courses during her work years. At the time of the data collection, the special needs assistant was finishing his studies in a physics and mathematics teacher education program, and in addition to the assisting tasks, he occasionally worked as a substitute teacher in the school.

4.2 Procedure

The mathematics teacher's eye-tracking data was collected with self-made gaze-tracking glasses with a setting developed in the MathTrack research project (Academy of Finland, 297856; e.g. Hannula et al., 2022) in the University of Helsinki. The devices recorded both the eye-movements and the view in front of the teacher. According to the developers (Toivanen et al., 2017), the gaze-trackers' mean accuracy is 1.17 degrees (weighted mean 1.55 degrees). A laptop computer located in a backpack of the user recorded the data. The device was calibrated before the first lesson and the same device was used in every lesson. Calibration was conducted with nine points manual coding by a technician. Due to the eye-model used in the analysis, one-time calibration was only needed in this case where participant use the same device in all recordings. After the data collection, gaze tracking videos were generated with MATLAB. The final video format included a 25Hz framerate. This will indicate shortest unit possible for analysis to be 40 ms, but we did not include gazes shorter than 80 ms into the data to avoid fixations too short for cognitive processing

(Galley et al., 2015). Additionally, a stationary video camera recorded the classroom activity and the verbal interaction. The personal data was stored safely on secured drive by the university and with access limited to the collaborating researcher. The anonymity of the participants was ensured before publishing.

All the lessons concerned geometry (angles and areas of plane shapes). One of the lessons included problem solving in groups, while the other three consisted of teacher's mathematics instruction, students making notes, and working on mathematics tasks from the textbooks. On all the lessons, the one teaches, one assists-method was used. The mathematics teacher was responsible for giving the general and mathematical instruction and for the class-level behavioral management, while the special needs teacher and assistant roamed among the students helping and encouraging them individually, and occasionally assisting the mathematics teacher with the learning materials.

4.3 Analyses

For the analysis, the researchers watched through the classroom video and the gaze recordings of the teacher. The first phase (research question 1) of the coding was the qualitative coding of teachers' visual attention to the teaching partners with ELAN software (Sloetjes & Wittenburg, 2008). Due to the explorative and naturalistic nature of this study, we chose dwell as a coding unit of teacher gaze. Dwell was defined as initial cohesion of fixations to an area of interest defined by the researchers (Haataja, 2021; Onuma et al., 2017). We defined the teaching partners of the mathematics teacher (special needs teacher or assistant) as the area of interest, and all the teacher dwells towards them were coded from the entry to the exit. Thus, the coded dwells comprise information on the area of interest and duration of each teacher gaze to the teaching partners. After coding the dwells, we watched the video with the audio again and, based on this observation, categorized the dwells according to their attentional purpose into Attentional and Communicative gazes (McIntyre et al., 2019). The gaze was coded as Attentional, when the teacher listened to the students or teaching partner, and Communicative, when the gaze occurred during teacher's instructions or lecturing. Additionally, we added a purpose category Other for those gazes that occurred without verbal interaction, for example, as a reaction to the teaching partner suddenly moving in the classroom.

The quantitative analyses were conducted with IBM SPSS (Version 29.0). The frequencies of the gaze categories were compared descriptively. For further analyses, the most extreme outliers (duration > 4000 ms, $n = 2$) were removed from the data. The mean durations of the gazes between categories were examined with t-test and Kruskal-Wallis H-test. Similar analytical approach in a mixed-method case study has previously been used for investigating the relation between gaze durations and qualitative coding categories (Haataja, Garcia Moreno-Esteva, et al., 2019), but we chose to use the nonparametric test, as the data was relatively small and not normally distributed (cf. Mangiafico, 2016), which is typical to gaze data. We report the effect sizes with squared

epsilon. When comparing the durations between the participants, the t-test and Mann-Whitney U test yielded comparable results, and we chose to report the t-test in this study.

For the research question 2, we continued by coding the pedagogical situation, during which the gaze took place. The pedagogical categories were General instructions (e.g., asking the students to start or end working), Whole-class mathematics instruction (lecturing mathematical contents to the class), Student scaffolding (helping individual students with mathematical tasks) and Other (e.g., preparing learning materials). Transcribed the classroom interaction and wrote descriptions of classroom actions especially before but also right after the coded dwells to contextualize the visual attention of the mathematics teacher to the teaching participants.

The cluster analysis was conducted using the SPSS TwoStep Clustering algorithm with the variables of instruction, gaze purpose, and gaze duration. This algorithm can use both continuous and categorical variables and identifies the clusters empirically instead of using a priori scheme. The TwoStep clustering uses a model-based distance measure measuring the decrease in log-likelihood between two clusters (Banfield & Raftery, 1993). Bayesian information criterion (BIC) was used to cluster selection to determine from the pre-clusters the final clustering with hierarchical clustering algorithm. We named the clusters inductively by the most essential categories determining the cluster itself. For example, the largest cluster consisted solely of gaze dwells from the purpose category Communicative and pedagogical situation category General instruction, and it was named as “Communicating general instruction”.

Finally, we used a qualitative approach to answer to the research question 3. A qualitative analysis is suitable for understanding the complexity and variety of teachers’ emotional triggers (Burić & Frenzel, 2019). The transcriptions and written descriptions were based on our observations on the stationary video recordings. The researchers observed the video recordings of the four lessons and annotated moments of either positively or negatively loaded interaction (cf. Uzuntiryaki-Kondakci et al., 2022). To these annotations, descriptions of the situation were added. We analyzed the qualitative descriptions of the instructional interaction during the teacher attention to the teaching partner.

In the analysis, we found emotional triggers occurring simultaneously with the coded gazes. With an emotional trigger, we refer to an incidence in interaction that differs from the goal-oriented instructional talk. These incidences could be observed through the change in the teacher’s tone of voice, use of language, and facial expressions. The researchers are experienced in observing interpersonal behaviors in educational contexts (e.g., Haataja et al., 2021) and have background as teachers themselves. We only divided the emotional triggers into positive and negative, as we did not collect the teacher’s self-reports on how he experienced the triggers. The positive emotional triggers (n = 6) included sharing exciting news, making jokes, and encouragement of students trying to work on the problem task. The negative triggers (n = 7) were moments such as responding to students’ disengagement, making a mathematical mistake, or struggling with technology.

5 Findings

5.1 Overview of the visual attention between teaching partners

To answer to the research question 1, we first provide an overview of the mathematics teachers' visual attention to the teaching partners. The mathematics teacher's total fixation time per lesson was approximately 50 minutes (that is 3000 seconds). During the four lessons, he looked at the teaching partners altogether 234 times (M = 483 ms, SD = 740 ms). Thus, the teachers' visual attention to the teaching partners constituted less than 4% of his visual attention in the lessons. Most of the gazes were short glances, half of the dwells being shorter than 280 ms, but also some long dwells of more than 2000 ms occurred (n = 7). The frequency of gazes to special needs teacher (n = 113, M = 403 ms, SD = 529) and special needs assistant (n = 121, M = 557 ms, SD = 891) distributed quite evenly, and there was no statistically significant difference in the gaze durations between the teaching partners ($t(197) = -1.619$, $p = .107$).

The purpose of the teaching-partner dyadic visual attention was most often communicative (n = 160). This was an expected finding, as the mathematics teacher was in charge of both general instructions and mathematical lecturing in the class. Altogether 24 attentional gazes and 50 other (not relative to verbal interaction) gazes were found. We found a statistically significant difference in the gaze duration ($H(2, n = 232) = 6.12$, $p = .047$, $\varepsilon^2 = 0.03$) between the rank totals of the purpose categories attentional gaze (147), communicative gaze (116), and other (105). The post hoc test indicated that the statistically significant difference emerged between gaze categories Attentional and Other, attentional gazes being longer than gazes without verbal interaction. The attentional gazes were infrequent but long in average. They took place during moments when the special needs teacher or assistant talked to the mathematics teacher or to the students, and the mathematics teacher focused on looking at her or him, instead of scanning briefly between the students.

5.2 Cluster comparison of gaze categories

When comparing the pedagogical situations during the attention between teaching partners (research question 2), 89 dwells occurred during general instructions, 76 during whole-class mathematics instructions, only 14 during scaffolding of individual students, and 55 during other behaviors, such as preparing learning materials. A Kruskal-Wallis H-test yielded a statistically significant difference ($H(3, n = 232) = 11.97$, $p = .007$, $\varepsilon^2 = 0.06$) between the rank totals of durations of General instruction (104), Whole-class mathematics instruction (120), scaffolding (85), and other (139). The post hoc test indicated that the gazes in category Other were longer than gazes in categories General instruction and Scaffolding. The high frequency and long duration of dwells at the teaching partner in the pedagogical category Other reflects the nature of the interaction between the teaching

partners during the lessons. Most of the verbal interaction was about practicalities, such as the seating of the students or searching for scissors or notebooks for the students. Only once did the mathematics teacher ask the special needs assistant to help in classroom management, and no mathematical verbal interaction between the teaching partners occurred.

The TwoStep cluster analysis was performed using instructional classification, gaze purpose classification, and gaze duration. The total of 232 gaze dwells were included in the analysis. The analysis identified four distinct cluster groups, all of them characterizing distinct kinds of intentions in interaction between the teaching partners (Table 1). Average silhouette measure of cohesion and separation was reported as 0.7, which is classified good. The most important predictor in the analysis was the pedagogical situation (importance = 1) followed by the gaze purpose (importance = 0.88), whereas the gaze duration was not highly significant (importance = 0.14). The distributions of gazes in purpose categories and pedagogical situations are presented in Table 1.

Table 1. The clusters of teacher's visual attention to a teaching partner

Cluster	**Proportion of Gaze Dwells (*n*)**	**Pedagogical Situation (*n*)**	**Gaze Purpose (*n*)**	**Mean duration (*SD*)**
Communicating mathematics instruction	29.7 % (69)	**Whole-class mathematics instruction** (69)	**Communicative** (69)	388 (295)
Communicating general instructions	32.8 % (76)	**General instruction** (76)	**Communicative** (76)	305 (238)
Attending to the teaching partner	17.7 % (41)	**Other** (26) General instruction (11) Whole-class mathematics instruction (2) Scaffolding (1)	**Attentional** (23) Communicative (15) Other (3)	883 (829)
Other	19.8 % (46)	**Other** (26) Scaffolding (13) General instruction (2) Whole-class mathematics instruction (5)	**Other** (46)	305 (242)

The largest cluster, Communicating general instructions, included 32.8 % of the dwells (n = 76). This cluster consisted solely of communicative dwells that occurred during mathematics teacher's general instructions to the students. The dwells in this cluster were short in average (M = 305 ms) and variation of the durations was relatively small (SD = 238).

The second cluster, Communicating mathematics instruction, included 29.7 % dwells (n = 69). This cluster included dwells from categories of communicative gaze purpose and whole-class mathematics instruction only. The dwells in this cluster somewhat longer and varied more (M = 388 ms, SD = 295) than in the Communicating general instructions cluster.

The cluster Other (19.8 %, n = 46) included gaze dwells that took place during the moments of no verbal interaction. Most of these dwells occurred during pedagogical situations that were not related to general or whole-class mathematics instruction or student scaffolding but concerned organizing the lesson or learning materials. This means, that during these gazes the teaching partners did not talk to each other or the students and were focused on organizing the learning materials or preparing for the next instructional sequence. The dwells in this cluster were the shortest in average (M = 305 ms, SD = 242)

The smallest and the most complex cluster of dwells was Attending to the teaching partner (17.7 %, n = 41). The mathematics teacher's dwells were the longest in this cluster (M = 883 ms, SD = 829). In this cluster, most of the dwells took place while the mathematics teacher attended to a teaching partner talking to him or to the students, but the cluster also included 15 dwells with communicative gaze purpose. The pedagogical situation was mainly classified as other, meaning that the teaching partners rarely interrupted the mathematics teacher's instructions or lecturing, and mainly talked between the sequences of goal-oriented instruction.

5.3 Emotional triggers and nonverbal interaction between teaching partners

Finally, we present the qualitative findings that answer to the research question 3. The qualitative analysis of the content of interaction during teacher gazes to teaching partners indicated that the verbal interaction often included an emotional trigger, when the mathematics teacher looked at the special needs teacher or assistant. All these gazes during emotional triggers were communicative, meaning that they occurred while the mathematics teacher spoke to the class. We found six dwells coinciding with negative emotional triggers, such as the teacher's mathematical mistake, struggle with learning technology, or expressing frustration by something controversial (e.g., "I don't care."). In these situations, the teacher often glanced at his teaching partner. For example, the mathematics teacher made a mistake during whole-class mathematics instruction. He was presenting an example task in front of the class, when he noticed an error in the definitions of certain plane shapes that he had drawn on his notebook, he first whispered to himself "Dummy!" He then measured the lines in the rhombus and noticed that by accident the lengths were equal and fitted in the definition. In this moment, he glanced at the special needs assistant saying: "Oh, shoot! I got lucky!" Then he scanned through the students, and once more looked at the special needs assistant when explaining his emotional expression.

Teaching-partner eye contacts also often took place during positive emotional moments, for example when the teacher encouraged uncertain students to propose their answer ("You don't have to know for sure, this was a tricky question, now we can start

pondering on it."), made a joke to the class (e.g. humorously comparing students to Pavlov's dogs), or introduced exciting news about the school's renovation plans. In these moments, the mathematics teacher expresses positive emotions with a friendly or excited tone of voice or laughter. Even though the jokes and news were addressed to the students, the mathematics teacher paid a lot of visual attention to the teaching partners in these moments.

Additionally, during a phase of evaluation of students' solutions for the problem-solving task, the teacher directed numerous gazes to the special needs assistant, ranging between 200 to 3160 ms in duration. This pedagogical situation may have been challenging to the mathematics teacher, as he gave both positive and negative feedback to the students in front of the whole class. For example, one student group presented a solution that was not mathematically sophisticated but quite innovative (connecting two points with curved rather than straight lines). The teacher encouraged them with an excited tone in his voice and asked other students to pay attention to this solution, even though he probably knew that mathematically it was not the optimal way to solve the task. Therefore, we interpret this instruction to be intuitive and situational rather than a pre-planned part of the lesson. In this moment, the mathematics teacher also attended to the special needs assistant, possibly seeking for collegial support to his decision.

6 Discussion

6.1 Characteristics of teacher attention to the teaching partner

Teacher's visual attention is mainly directed to students and teaching materials across teaching contexts, contents, and cultures (Chaudhuri et al., 2022; Haataja, Garcia Moreno-Esteva, et al., 2019; McIntyre et al., 2019), and whereas adult-adult visual eye-contact interaction and its relations to actions and affects in the classrooms has remained unexplored. According to the findings of this mixed-method case study, the mathematics teacher's visual attention to the special needs teacher and the special needs assistant was minor to his attention to the students and the learning materials. The roles of the teaching participants were typical for Finnish education (cf. Sundqvist et al., 2023): The lessons were constructed according to the one teaches, one assists-method, and the special needs teacher and assistant were verbally quite passive, mostly only whispering to individual students. Still, mathematics teacher's gazes to direct the work of the teaching partner and teaching partners' visible reactions to the mathematics teacher's attention were rare. All the adults seemed to have pre-planned roles in the class, as recommended in the Finnish national curriculum (Finnish National Agency for Education, 2014). Interestingly, despite the other teaching partner being a professional teacher and the other working as a special needs assistant, and despite the variety of instruction and interaction among and between the recorded lessons, the mathematics teachers' visual attention to the teaching partner was relatively similar and coherent across the data.

The findings on the research questions 1 and 2 indicated that the most of the eye contact interaction between the teaching partners emerged during the mathematics teacher's general instruction or whole-class mathematics instruction to the class, and these communicative gaze dwells to the teaching partner were often short glances. However, during the short moments of verbal interaction between the teaching partners, the mathematics teacher attended to the teaching partner with long dwells. Previous research has presented that teacher's gaze behavior can roughly be divided between frequent short glances, when scanning through the students' faces, and infrequent long dwells, during communicating to individual students or paying attention to the student work (Haataja et al., 2021). This preliminary study indicates that between-adult interaction in the classrooms is similar. And most importantly, the long, rare gazes differ qualitatively from short, common gazes.

None of the moments of the mathematics teacher's attentional gaze to the teaching partner included talk about mathematics, but mainly issues concerning organizing the lessons. The instructional interaction by the special needs teacher and assistant mainly happened with individual students, not with the mathematics teacher or the whole class. Again, the students talked to the mathematics teacher mainly when answering his questions (cf. Spörer et al., 2021). The students may have felt more immediacy from the teaching partner in the "assisting" role (Webster & Blatchford, 2013). In future, investigating how the pre-planning and retrospective self-reflections between the teaching partners, and their in-situ verbal and nonverbal interaction in the classrooms comprehend each other. The very subtle nature of verbal and nonverbal interaction between the teaching partners during the lessons highlights the need for space and time for careful interaction outside the lessons.

6.2 Emotional triggers during the attention to the teaching partners

The qualitative analysis answering research question 3 suggested that emotional triggers in the verbal interaction often coincided with eye contacts between the teaching partners. When the mathematics teacher made mistakes or gave negative feedback on a students' solution, he often glanced at the teaching partner, as if checking their reactions or seeking for collegial support. Making mathematical errors may trigger shame in teachers (Jenßen, 2021), and seeking for an eye contact in these moments indicates that the relationship was meaningful to the mathematics teachers on an unconscious level. However, whether the mathematics teacher looked at the teaching partner to decrease feeling ashamed or to seek for comfort, cannot be concluded without additional data sources, such as physiological measurements, in-situ self-reports, or gaze-stimulated retrospective reflection. Still, form our data we could see that the teaching partners did not react to these eye contact initiatives by any other means than just looking back, and the mathematics teacher continued the instruction after these moments without struggles. As collegial connectedness is important for teachers' emotional wellbeing, teaching partners' supportive gestures could be important for the teacher to sustain positive emotional state and confidence in teaching

(Bower & Carroll, 2017; Parker et al., 2012).

Additionally, during positive moments of making jokes or sharing exciting news, the teacher frequently looked at the teaching partner. In previous research, the teachers have been found to acknowledge the need to share emotions with the teaching partner but have reported that they rather share positive than negative emotions (Muehlbacher et al., 2022). However, our findings suggest that on nonverbal level, the collegial contact was present also during challenges. Teachers have a need for collegial support in the context of co-teaching (Pesonen et al., 2021), and these subtle gestures of acknowledging the other adult in the classroom can be interpreted as microlevel building blocks of supportive collegial relationships (cf. Haataja et al., 2021).

This finding underlines the need for combining video observations and physiological measurements in classrooms to understand the shared attention and emotions. Naturally, we cannot interpret the teacher's inner emotional experiences based on researchers' video observation, nor can the teaching partner know how the other teacher feels without asking. Thus, the interplay of the observable expressions, the inner experiences, and the participants' reflections on these two would be an essential research topic for the future. The teachers and special needs assistants may need momentary support from each other to overcome emotionally challenging situations in classroom interaction, and this support may be very subtle. This adds to the theory of dualistic nature of teacher attention (cf. Jarick & Kingstone, 2015): the communicative gaze to students may actually be attentional to the teaching partner. Even when the teacher lectures during the scanning attention through the class, they may seek for support from the colleague with their gaze.

6.3 Limitations and future research

The limitations of this study mainly yield from its nature as a single case study. In studies with small samples, the selection of the time and place of data collection may affect the findings (Maag Merki et al., 2022). Our case represents a usual setting in Finnish lower secondary school: the subject teacher and a special needs teacher or assistant forming a team that uses the one teaches, one assists-method. Therefore, we suggest that these findings, even if they on some level reflect the individual characteristics of the participants, can be applied to other similar settings. Additionally, the nature of the gaze data affects the possibility of in-depth interpretations, and therefore the case study approach is established in naturalistic educational mobile eye-tracking studies (Chaudhuri et al., 2022).

The characteristics of eye tracking data also challenges the use of quantitative analyses: gaze data usually consists of numerous short gazes and few very long gazes and is therefore rarely normally distributed. However, parallel analytical approach has been used in many studies on teachers' visual attention (Määttä et al., 2021; Van Driel et al., 2021), and we adopt the ideal of using data triangulation for the validity of the interpretations.

We found no difference in mathematics teacher's attention between the two teaching partners despite the difference in their roles. The special needs teacher was a qualified

teacher, whereas the special needs assistant was a teacher student working in an assisting role. They both received similar amount of attention from the teacher, and in similar situations This may be affected by their background: during the data collection, the special needs assistant was finishing his studies to become a mathematics teacher. Therefore, the mathematics teacher may have understood him as more of a colleague than an assisting person, especially with regards to content-knowledge related aspects. Previous research indicated that subject teachers and special needs assistants focus on different aspects in teaching collaboration (Paju et al., 2022), but in our study the assistant seemed to be in the middle of these roles. In future, larger samples of participants and retrospective interviews relating the participants' interpretations on their attentional patterns could help in characterizing the variation of eye contact interaction between the professionals in school. Especially, comparing eye-contact interaction behaviors between the teacher groups, levels of expertise, or teachers' relations to each learning content or student group could help in bringing these preliminary findings towards a more established and generalizable knowledge.

This case study was the first step to chart and characterize the visual attention between teaching partners. For example, we noticed that during the lesson of problem solving, the teacher gaze to special needs assistant was quite frequent. Still, we only had one problem solving lesson and three other lessons, and thus we aimed at in-depth reflections rather than in generalizability of the findings. Additionally, we interpreted emotional triggers on the video recording, but did not use physiological measuring on teacher emotions. As teacher emotions are a complex phenomenon, where the inner experiences often differ from the expressions, we cannot interpret how the teacher really felt, only the content of the verbal interaction as a possible trigger to teacher emotions. We wish to examine co-teacher nonverbal interaction with more participants in the future to understand, how the attentional patterns relate to the teacher's intentions and mathematical objectives. Specifically, connecting these situational behaviors of nonverbal interaction to students' learning in the mathematics lessons is a research gap that should be addresses in the future.

Conclusion

The students are, and they ought to be the most important gaze target for all teachers in the classroom. However, co-teaching professionals share the situational work that is both cognitive, emotional, and social. This case study was the first step in our aim to understand the reciprocal, situational, and intentional nonverbal interaction between co-teachers and teaching partners in authentic classrooms. We suggest that future research and teacher education should provide teachers with tools to improve their situational nonverbal interaction for the possibilities to share intentions, immediacy, and sustainability in collegial relationships. For this, the teachers' need and practical tools for in-situ nonverbal collegial support to decrease the emotional load or to meet the challenges of classroom management should be further investigated.

Research ethics

Author contributions

Haataja, E.S.H.: conceptualization, formal analysis, investigation, methodology, visualization, writing—original draft preparation, writing—review and editing
Salonen R.V.: formal analysis, investigation, methodology, writing—original draft preparation, writing—review and editing

All authors have read and agreed to the published version of the manuscript.

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Informed consent statement

Informed consent was obtained from all research participants and the students' care givers.

Data availability statement

Video and eye-tracking recordings cannot be shared due to confidentiality. Information on the data set can be found in Klette, K. (2022). *Quality in Nordic Teaching (NCoE) Common QUINT Dataset 2022* (Version 1). Zenodo. https://doi.org/10.5281/ZENODO.6381818

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Conflicts of interest

The authors declare no conflicts of interest.

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