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Classroom chronicles: through the eyeglasses of teachers at varying experience levels

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Introduction: Teachers face the intricate task of managing diverse classroom situations, directly affecting student learning outcomes. Many preservice and beginning teachers, however, find classroom management challenging. Effective classroom management hinges on the teacher's ability to notice and interpret visual cues that signal potential issues - a proficiency termed 'professional vision.'

Methods: In this study, we used mobile eye-tracking glasses to assess the professional vision of 22 preservice, 17 beginning, and 19 experienced teachers as they instructed their classes.

Results: Our findings revealed no discernible differences in the efficiency of visual processing across varying teaching experience levels throughout the lesson. Interestingly, by the lesson's end, preservice teachers demonstrated a slight uptick in fixation counts compared to the onset. As for perceptual span, overall teaching experience did not significantly influence the dispersion of fixations, though experienced teachers exhibited a more expansive visual span at the lesson's commencement than its conclusion. In examining mental effort, teaching experience did not notably impact the average fixation durations. Yet, preservice teachers registered a subtle decrease in fixation durations as the lesson progressed to its end. In conclusion, this study showed that professional vision manifests differently across teaching experience levels.

Discussion: Given its nuanced influence on classroom management and student engagement shown in prior research, our study underscores its importance in pedagogical training.

KEYWORDS

eye tracking, mobile eye tracking, teacher, expertise, visual expertise, professional vision, classroom management

1 Introduction

Picture yourself as a secondary school teacher standing in front of a classroom filled with teenagers engaged in all sorts of off-topic activities. To your left, a group of pupils is lost in casual conversation rather than the lesson. To your right, a pair of pupils fiddles with a mobile phone. The digital learning board you rely upon is malfunctioning, while a pupil right in front of you raises a hand, eager to pose a question. Amidst this, which event do you tackle first? What considerations guide your decisions in this moment?

What you just read, is part of the teachers' daily practice, where a lot is going on that the teachers must somehow manage (Berliner, 2001). The technical term for this is 'classroom management' and it refers to managing pupils with the aim to create an atmosphere that encourages their learning (Brophy, 1988; Doyle, 2006). It is not only necessary to keep order during a lesson, but far more important, it enables pupils to learn (Berliner, 2001; Hattie, 2009). However, it is a skill, that teachers often struggle with in their daily practice (Van Tartwijk et al., 2011). Effective classroom management requires that teachers notice and monitor what is going on in the classroom and that they meaningfully interpret what it means for their actions to encourage pupils' learning – a skill referred to as 'professional vision,[1] (Berliner, 2001; Van Es and Sherin, 2002; Sherin, 2014). This is a skill that a lot of beginning teachers struggle with, and many experienced teacher excel in (Sabers et al., 1991). This phenomenon has been studied by means of diverse methods (Skuballa and Jarodzka, 2022), of which eye tracking – a method to measure where a person looked (Holmqvist et al., 2011; Jarodzka et al., 2021) – has proven to provide particularly interesting insights (Lachner et al., 2016; Jarodzka et al., 2021; König et al., 2022). Eye tracking can directly capture, what a teacher is able to pick up from a video recording of other teachers' authentic classroom situations (Yamamoto and Imai-Matsumura, 2013; Van den Bogert et al., 2014; Wolff et al., 2016) or in an simulated teaching scenario (Stürmer et al., 2017). Research, on teachers professional vision during actual teaching classrooms, however, is still limited (for exceptions, see Cortina et al., 2015; McIntyre et al., 2019; Haataja et al., 2021; Chaudhuri et al., 2022).

Here we present first analyses of eye tracking recordings from a larger data set (Van Driel et al., 2022), where we compared teachers in different career stages, namely, *pre-service* teachers, who are still studying to become a teacher, *beginning* teachers right after having entered the work and field, to *experienced* teachers, who have been working in this field for at least 10 years. Our aim is to gain a deeper understanding of how teachers, in these different stages of their careers, deal with the constant flow of rich and dynamic information reaching them as triggers for (potential) actions to successfully manage a classroom.

2 The role of visual processes in expertise

In the current study we want to take the perspective of the teacher as an expert (Bromme, 2014). Experts are individuals who perform repeatedly better on a set of tasks that are representative for a certain domain (Ericsson et al., 2018). This phenomenon has been widely investigated within specific well-defined domains, such as chess (e.g., Gobet and Charness, 2018; Lane and Chang, 2018) or medicine (e.g., Choudhry et al., 2005; Boshuizen and Schmidt, 2008; Norman et al., 2018). Already early on, it became clear that visual processes play a critical role in the expertise of an individual (e.g., Chase and Simon, 1973; Lesgold et al., 1988; De Groot and Gobet, 1996). The best way to study these visual processes is to use eye tracking (Duchowski, 2003; Holmqvist et al., 2011; Liversedge et al., 2011). The eye tracker is an apparatus that records the eyes of a person looking around, to deduce, which element this person was looking at, for how long, and in which order.

Eye tracking studies showed early on, that the perceptual aspect of expertise in chess are characterized by two features, namely, a larger visual span and more efficient visual processing of individuals with higher expertise (De Groot and Gobet, 1996; Reingold et al., 2001). These two aspects were indicated by fewer fixations and by fixations located in between several chess pieces instead of on individual chess pieces, which indicates that experts encode information from a broader area than individuals with less experience in chess. Similarly, eye tracking studies in medical fields (mainly in radiology) have shown that experts process medical images more efficiently (Krupinski et al., 2013; Van der Gijp et al., 2017; Nodine and Mello-Thoms, 2018) and that they can extract information from the periphery far better than individuals with less experience, indicating a larger visual span (Kundel et al., 1991; Jaarsma et al., 2015; Sheridan and Reingold, 2017).

However, understanding and describing expertise in more ill-structured domains is more difficult to grasp empirically, and a rather recent development in the research field of expertise studies (Boshuizen et al., 2020). One example of such an ill-structured domain where visual processes seem to play a critical role is teaching (Lachner et al., 2016; Jarodzka et al., 2021; Skuballa and Jarodzka, 2022). For instance, the model of Lachner et al. (2016) shows that professional vision of teachers shapes their practical knowledge base, activates their curriculum scripts (i.e., elaborated organized knowledge structures, see Putnam, 1987), which in turn guide teachers' teaching practices, indicating the central role of visual[2] processes in teaching (Lachner et al., 2016). Van Es and Sherin (2002) describe teachers' professional vision as the ability to notice relevant events taking place in the classroom and to interpret them effectively. Over recent years, although being still scarce, eye tracking has increasingly been used to study this professional vision of teachers and offering first pivotal insights while simultaneously raising pressing questions.

The first question that arises is, whether one aspect underlying teaching experience could be the *efficiency in visually processing* a classroom. Such a question has already been studied in eye tracking research extensively under the term 'visual search', where participants look for targets amongst a set of distractors (Wolfe, 1994, 2007; Wolfe and Horowitz, 2017). Usually, either time to find the target or the number of fixations made while searching serves as indicator for efficiency of visual processing. Already early on, eye tracking research found that the number of fixations during task performance is negatively correlated with search efficiency (Goldberg and Kotval, 1999): while a higher number of fixations is indicative of difficulties in interpreting the fixated information (Ehmke and Wilson, 2007), lower number of fixations may signify expertise in a task (Rötting, 2001). Consequently, this research question was pursued widely within expertise research: This phenomenon has been observed across diverse domains, encompassing chip inspectors (Schoonahd et al.,

1 Sometimes this is also referred to as 'visual expertise'. Both terms originate from different research fields, but refer to the same phenomenon and could be used in the case of the current article interchangeably.

2 In educational practice, auditory cues are equally important. This is, however, out of scope of the current study.

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1973), inspectors of diverse industrial products (Megaw and Richardson, 1979), chess players (Reingold et al., 2001), and pathologists (Krupinski et al., 2006). This was corroborated by a meta-analysis of different eye tracking measures across expertise studies from diverse domains, in which Gegenfurtner et al. (2011) found that over 43 studies, experts exhibited slightly fewer fixations compared to novices. Notably, contrasting effects have been identified in other contexts, including pilots (Kasarskis et al., 2001), volleyball players (Afonso et al., 2012), and football players (Williams et al., 1994). Contrary, Sheridan and Reingold (2017) found in their literature review that the number of fixations increases with increasing expertise. Hence, we can conclude that, although findings vary broadly, there seems to be an interaction between the experience someone has in a task and the number of fixations during task performance. Recent eye tracking studies hint towards this phenomenon also playing a role in the teaching domain, which differs largely from the earlier mentioned domains of chess or medicine using mainly static stimuli, in that classrooms are highly dynamic and multidimensional (Doyle, 2006). Studies using eye tracking technology while watching video recordings of other teachers' classroom lessons have shown that experienced teachers display shorter fixations, yet more effective monitoring skills (Van den Bogert et al., 2014). Their perception seems more knowledge-driven and less distracted by irrelevant or salient events compared to novices (Wolff et al., 2016). First mobile eye tracking studies of teachers teaching their own classes further substantiate these findings, allowing a more ecological analysis of visual perception in authentic teaching situations (Cortina et al., 2015; Chaudhuri et al., 2022). We can thus conclude that with increasing experience teachers tend to display increasingly more efficient visual processes. It is, however, not entirely clear, yet, how this reflects in concrete eye tracking measures, that is, whether the number of fixations de- or increases when teaching own classrooms.

A second question would be to which extent the *visual span* changes with increasing teaching experience. This phenomenon has been already widely studied with eye tracking in reading research (Rayner, 2009). In the studies most of the text is disguised while only a small part at the current point of focus is visible (so-called gaze-contingent moving-window paradigm: McConkie and Rayner, 1975). In such studies readers have been found to process information from a region extending roughly 3–4 character spaces to the left of the fixation point to about 14–15 spaces to the right (e.g., Rayner et al., 1982; Underwood and McConkie, 1985). However, the perceptual span varies with reading experience. Beginning readers and those with dyslexia, for instance, display smaller spans compared to more skilled readers (Rayner, 1986; Rayner et al., 1989). This has also been studied in expertise in the domains of medicine and chess (for a comprehensive review on expertise differences in the visual span in the domains of medicine and chess, see: Sheridan and Reingold, 2017). It often related to the concept of 'chunking' introduced by Miller (1956), which describes the ability of persons with higher experience in a certain task to group information into larger, meaningful units. Chase and Simon (1973) and Simon and Chase (1973) explored this in the context of chess, suggesting that experts develop advanced memory structures for chunks of chess figures. These memory structures, acquired through extensive practice, allow experts to swiftly encode configurations in terms of larger patterns, emphasizing the significance of professional vision in recognizing overarching patterns rather than discrete features (Gobet and Charness, 2018). The finding that individuals with increasing expertise develop a larger visual span, has been also found in other domains, such as medicine (e.g., Jaarsma et al., 2014; Van der Gijp et al., 2017) or aviation (e.g., Demaio et al., 1978; Kim et al., 2010; Peißl et al., 2018). In teaching, where classrooms are characterized by very dynamic events and many of them happening at the same time, experienced teachers tend to cover more areas of the visual display, demonstrating a broader attentional scope (McIntyre et al., 2019). Beginning teachers, in contrast, may show more focused attention on a small group of students, particularly in feedback provision, reflecting a narrower visual span (Cortina et al., 2015). In addition, we also know that teachers with high levels of experience in teaching have built up complex knowledge structures called 'classroom management' or 'curriculum' scripts that are a similar concept to the above-mentioned chunks (Lachner et al., 2016; Wolff et al., 2021). This would support the idea that the scripts could also enable teachers to develop a larger visual span. This concept has, however, to this day, not been directly, tested for teachers while teaching their own classrooms.

A third question that occurs is whether the *mental effort* teachers experience during teaching changes with higher levels of experience in teaching. Recent reviews have shown that the mental effort experts experience in comparison to novices declines as measured by eye tracking (Gegenfurtner et al., 2011; Peißl et al., 2018; Gil et al., 2022). Mental effort can be captured by means of eye tracking as the duration of fixations (Holmqvist et al., 2011). Eye tracking research has proven repeatedly, that shorter durations of fixations indicate a higher mental effort (Gog et al., 2009; Hyönä, 2010; Van Mierlo et al., 2012; Korbach et al., 2016; Dirkx et al., 2021). Indeed, expertise has been shown to be related to longer fixation durations in diverse domains, such as chess, art (Nodine et al., 1993; Reingold et al., 2001; Reingold and Charness, 2005). However, sometimes the opposite has been found (Gegenfurtner et al., 2011; Sullivan et al., 2011; Jaarsma et al., 2014; Yu et al., 2022) or no effect at all (Lee et al., 2019). Thus, we can assume that the effect of expertise and fixation durations depends to a large extent on the specific task and the stimulus (Bertram et al., 2013). Yet again, it is not trivial to draw conclusions from other areas of expertise research, which mostly study static pictures, to the teaching domain, where the 'stimulus' is highly dynamic and multidimensional with many things happening at the same time (Doyle, 2006). Recently, Chaudhuri et al. (2022) studied with mobile eye tracking how teachers visually processes first-grader classrooms. They found that teachers' fixation durations correlated with students' academic skills and individual support levels, suggesting that student distribution affects how evenly a teacher can allocate their visual attention in the classroom. We do not know yet, however, to which extent teachers' mental effort can be measured by mobile eye tracking when teaching their own classrooms, and how this relates to their level of experience in teaching.

A final question it occurs is weather these above-mentioned concepts are stable over the entire lesson or whether they *change over time*. It is very difficult to draw conclusions from prior research as most eye tracking studies are very short and come nowhere near to the duration of a full lesson. However, there are some indications that visual processes of experienced professionals change over time in a different way than those of less experienced individuals (Jaarsma et al., 2014). It is unclear to which extent this is also true for visual processes of teachers while teaching entire lessons.

3 This study

We can conclude that the exploration of teachers' visual perception through video-based and classroom-based eye tracking studies offers significant insights into the nuanced differences between more and less experienced teachers. These findings may have implications for teacher training and development, emphasizing the importance of fostering efficient visual processes, expanding visual span, or managing mental effort. The research also highlights the potential for further investigation of classroom-based mobile eye tracking to better grasp the complexity of teaching in authentic classrooms. However, eye tracking research while teaching one's own authentic classrooms is still scarce and thus, many questions remain open. Hence, in the current study we investigated three research questions:

1. Do more experienced teachers demonstrate more efficient visual processes compared to their less experienced counterparts?
2. Is the size of the perceptual span influenced by a teacher's amount of teaching experience?
3. Does the mental effort exerted during teaching vary among teachers with different levels of experience?

Furthermore, for each of the three research questions, we explored whether the phase of the lesson influences teachers' visual processing of their classroom.

4 Methods

This submission is part of a larger data set as described in Van Driel et al. (2022). Other publications stemming from this recording, but addressing different data streams, are on interviews with the teachers (Van Driel et al., 2023) and on their signaling of events relevant for classroom management (Van Driel et al., 2021). This research was approved by the ethical committee of the Open University (U2016/08859/FRO).

4.1 Participants and design

Participants were recruited from secondary schools and teacher training institutes in the Netherlands. Three groups of teachers were compared: 22 *preservice* teachers ($M = 22.82$, $SD = 2.65$ years; 55% female) in the third or fourth year of teacher education; 17 *beginning* teachers ($M = 25.82$, $SD = 2.94$ years; 41% female) after their transition to the workplace and having an average of 2.5 years of teaching experience; and 19 *experienced* teachers ($M = 45.00$, $SD = 8.82$ years; 53% female) with at least 10 years of teaching experience in secondary education. Due to the eye tracking nature of the study, only participants with normal vision or corrected-to-normal vision with soft contact lenses were included.

These three groups were eye tracked while teaching their regular classes for one lesson of their choice, which resulted in varying subject, such as geography, history, English, mathematics, etc. [duration: M $(SD) = 44.21$ (5.56) minutes]. From these recordings, three eye tracking measures were derived: *count*, *average duration*, and *total dispersion* of fixations. Additionally, these measures were compared across the *beginning*, *middle* and *end* phase of the lesson. The beginning of the lesson demarked the moment that all pupils were seated and the teacher started the lesson. The lesson ending demarked the moment that the teachers had finished the lesson and pupils started to stand up from their seats to leave the classroom. The time between beginning and ending of the lesson was divided into three phases (equal in duration; M $(SD) = 14.74$ (1.85) minutes) and labeled as beginning, middle and end phase of the lesson.

4.2 Apparatus

Eye tracking data were collected with the SMI 60 Hz eye tracking glasses.[3] These glasses have one camera in the center of the frame directed towards the point of view of the teacher, which is continuously recording the scene towards which the teacher directs their head. Additionally, six infrared lights are built into the frame and directed towards the teacher's eyes. Two infrared cameras, that are built into the lower part of the frame, record the teacher's eyes. Resulting eye tracking data was analyzed with SMI Begaze software (version 3.7.59).

4.3 Procedure

Before the recordings, teachers received information about (i) the nature of this study (i.e., studying the role of professional vision for classroom management in teachers of different experience stages), (ii) requests towards the lessons (i.e., no changes to the sitting arrangements or content of the lessons, but request to include diverse learning activities), and (iii) the procedure of the recording (i.e., eye tracking during lessons, interviewing afterwards). In parallel, parents and students were informed about this study and were asked for consent.

During the recording, teachers wore eye tracking glasses during one entire lesson. To adjust these glasses to each individual person, the experimenter calibrated and validated each teacher with three points and repeated a validation at the end of the lesson. Teachers were instructed to indicate with an inconspicuous hand gesture when they experienced a remarkable classroom management event during teaching. The analysis of these data is already published and out of scope of the current article (Van Driel et al., 2021).

After the recording, teachers were interviewed based on the recorded videos. These data are not part of the current article and are already published elsewhere (Van Driel et al., 2023).

The entire data collection took place in 2017 and 2018.

4.4 Data analysis

The here described recordings resulted in 216.95 GB of eye tracking data. The average tracking ratio was 94.2% ($SD = 3.5$). To ensure sufficient data quality, all recordings below a tracking ratio of 80% were excluded. The remaining recordings were visually screened for substantial data loss or off-set of the recorded teachers' visual focus. Furthermore, we decided to perform the analysis on classes where pupils were sitting in rows and this resulted in a final dataset of

3 www.smivision.com, discontinued.

45 teachers of which 16 preservice teachers, 14 beginning teachers and 15 experienced teachers. Teachers, in whose lessons students were sitting in other sitting arrangements (e.g., arts lessons, where students were sitting in groups) were excluded for the current eye tracking analyses to ensure a somewhat comparable visual setting.

Next, eye movement events were detected within raw data streams with SMI's algorithm for mobile eye tracking data. We applied settings to define saccades of below 100°/s or above 8°/s and a minimal skewness of 5 and fixations of at least 50 ms duration. Three measures were derived from these fixations: their total count, their average duration, and their dispersion.

We used ANOVAs with an $\alpha < 0.05$ to test whether the different eye movement metrics differed according to expertise level of the teachers. In a next step, we used mixed-effects models to examine whether the different eye movement metrics (i.e., count, average duration and dispersion) differed according to lesson phase (beginning, middle, end) and expertise level (preservice, beginner and experienced). The analysis was carried out in R and Rstudio (version 2023.03.1). For each eye movement measure, a separate mixed model was estimated with the eye movement measure as dependent variable, with expertise level, lesson phase and their interaction as fixed effects and with participant as random effect using the lme4 package (version 1.1–33; Bates et al., 2015). The lmerTest package was used to obtain *p*-values (version 3.1–3; Kuznetsova et al., 2017). The performance package was utilized to obtain the marginal and conditional R2 of the models (version 0.10.4; Ludecke et al., 2021). Additional *post hoc* comparisons were performed with the emmeans package (version 1.8.6, Lenth, 2022).

5 Results

Means and standard deviations can be found in Table 1. The output of the mixed effects models can be found in Table 2.

5.1 Efficiency of visual processing

No significant differences were found for count of fixations during the overall lesson, $F(2, 42) = 0.03$, $p = 0.97$, $\eta^2 = 0.001$. This indicates that there are no overall advantages in efficiency of experience on visual processes. Count of fixation did also not differ between preservice, beginning and experienced teachers during the different lesson phases (Table 3). During the end phase of the lesson, preservice teachers show a marginally significant increase in fixation counts compared to the beginning phase ($p = 0.06$, Table 4). 82% of the variance in fixation count was explained by both the random and fixed effects and 1% of the variance was explained by the fixed effects (i.e., expertise and lesson phase) only. For means and standard deviations see Figure 1 and Table 2.

5.2 Perceptual span

There was no significant effect of expertise on the total dispersion of fixations, $F(2, 42) = 0.64$, $p = 0.53$, $\eta^2 = 0.03$. Looking at the different phases of the lesson, results show that experienced teachers have a larger visual span at the beginning of the lesson compared to the end of the lesson (Table 3, $p = 0.04$). 76% of the variance in average fixation dispersion was explained by the full model, while 5% was explained by expertise level and lesson phase only. For means and standard deviations see Figure 2 and Table 2.

5.3 Mental effort

There was no significant effect of expertise on the average duration of fixations, $F(2, 42) = 1.24$, $p = 0.30$, $\eta^2 = 0.06$. Looking further to the different phases of the lesson, results show again a changing pattern for preservice teachers (Figure 3). Preservice teachers show a marginally significant decrease towards the end phase of the lesson compared to the beginning ($p < 0.08$) and middle phase ($p < 0.08$) (Refer to Table 4). This indicates that preservice teachers experience less mental effort during the end phase of the lesson. 79% of the variance in average duration of fixations was explained by the full model and 5% of the variance was explained by the fixed effects only (i.e., expertise and lesson phase) (Refer to Table 2).

6 Discussion

6.1 Preservice teachers struggle towards the end of the lesson

The present study aimed to investigate the efficiency of teachers' visual processing in terms of the *number of fixations* made, depending on their level of experience (Research Question 1). Our findings did not reveal any significant differences in the count of fixations during the overall lesson among preservice, beginning, and experienced teachers. This suggests that, overall, there are no advantages in visual processing efficiency based on teaching experience. These results contradict previous findings in other domains, which were, however, mixed. It is possible that the nature of the teaching task and the complexity of classroom environments contribute to the different outcomes observed in our study. It is in line though, with our previous analyses of other data sources from this study, where we found no differences between the number of challenging classroom situations identified by all three teacher groups (Van Driel et al., 2021) nor in how they talk about these situations (Van Driel et al., 2023). Another study on teachers' efficiency of visual processes did find differences between more and less experienced teachers: McIntyre et al. (2017) found that expert teachers have more efficient visual processes, with a focus on student-centeredness, compared to novices. Their gaze is more often directed at students, indicating a priority for student engagement and feedback. These researchers, however, focused in their study primarily on student-teacher interactions within two different cultural contexts (Hong Kong vs. UK), which might have contributed to coming to different conclusions than we do in our current study. In a more comparable cultural context (i.e., German) Stürmer et al. (2017) found that preservice teachers face challenges in maintaining consistent attention in classroom settings, frequently shifting their focus and possibly not processing relevant classroom information as efficiently as their experienced counterparts. However, they did not compare these preservice teachers to more experienced counterparts.

Additionally, the count of fixations did not differ between the different lesson phases for preservice, beginning, and experienced teachers. This implies that the visual processing patterns remained

TABLE 1 Means and standard deviations.

	Fixation count			Fixation average duration			Fixation average dispersion		
	Preservice	Beginner	Experienced	Preservice	Beginner	Experienced	Preservice	Beginner	Experienced
Beginning	2.27 (0.31)	2.25 (0.30)	2.23 (0.29)	311.30 (55.85)	335.39 (48.58)	332.03 (51.97)	113.87 (29.35)	123.53 (32.22)	128.97 (33.20)
Middle	2.31 (0.33)	2.23 (0.37)	2.24 (0.29)	310.71 (43.87)	342.25 (61.25)	330.51 (52.40)	104.46 (26.33)	119.38 (29.57)	117.30 (34.16)
End	2.35 (0.30)	2.23 (0.33)	2.24 (0.23)	297.49 (38.38)	336.18 (56.36)	329.68 (44.50)	106.15 (24.09)	111.17 (23.26)	117.41 (34.84)
Overall	2.26 (0.28)	2.24 (0.32)	2.27 (0.23)	310.53 (42.21)	335.56 (49.40)	322.45 (38.32)	108.90 (24.43)	117.36 (26.66)	119.73 (32.36)

consistent throughout the lesson, regardless of the teachers' experience levels. However, a marginally significant increase in fixation counts was observed for preservice teachers during the end phase of the lesson compared to the beginning phase. This finding suggests that preservice teachers become less efficient during the later stages of the lesson. This might be the case, because they either get more accommodated to teaching their lesson or because they must speed up as they might be running short on lesson time. Another possible, albeit related, explanation would be that they experience more stress and mental effort resulting in faster visual processes. We cannot exclude other potential factors, such as specific behaviors of the students, the taught subject or the time of the day, could have influenced their visual processing as well. However, such factors should not have varied systematically within one teacher group only.

Regarding Research Question 2, our results suggest that while there is no overarching effect of teaching experience on the overall dispersion of fixations, there exists a nuanced interplay between experience and specific lesson phases. Specifically, experienced teachers appear to exhibit a broader *visual span* at the lesson's commencement, which narrows as the lesson progresses. This finding is particularly interesting when contextualized against prior research. Drawing from the foundational literature, the modulation of visual span with experience is a well-documented phenomenon in various domains, from reading to chess. In teaching, previous studies have highlighted experienced teachers demonstrating a wider attentional scope, juxtaposed against beginning teachers' more concentrated attention, especially during feedback provision (Cortina et al., 2015; McIntyre et al., 2019). This notion finds resonance in the concept of 'chunking', where experts, through extended practice, develop an ability to process larger, overarching patterns rather than isolated features (Chase and Simon, 1973; Gobet and Charness, 2018). The theoretical concept of 'classroom management scripts' in teaching, similar to 'chunks,' suggests that teachers with advanced experience cultivate intricate knowledge structures, potentially enabling them to encompass a more expansive visual span (Wolff et al., 2021). However, in the current study, we did not assess to which extend the experienced teacher group indeed possessed higher levels of expertise in terms of classroom management. Our sample could have included experienced teachers with varying levels of expertise in classroom management, which in turn, would have limited the ability of chunking of part of this group and thus tainted our results. Still, our findings are in line with other research, such as by Stürmer et al. (2017), who found that preservice teachers exhibit challenges in evenly distributing their attention among students. These findings are corroborated by two other studies explicitly focusing on teachers with different experience levels: Cortina et al. (2015) suggest that while novice teachers might overly focus on specific students, especially when giving feedback, experienced teachers tend to maintain a broader attention span, distributing their gaze more evenly across the classroom, even when providing feedback. This ability to manage attention might be a key factor in their more effective classroom management. McIntyre et al. (2017) showed that experienced teachers demonstrate a strong student-centered approach in their attention distribution, with a consistent and flexible gaze towards students. Novices, in contrast, show a higher tendency to be distracted and have a more variable approach in their communicative gaze. Given this backdrop, our findings underscore the dynamic nature of

TABLE 2 Output of the mixed effects models.

	Fixation count				Fixation duration average				Fixation dispersion average			
Random effects	Variance	*SD*			Variance	*SD*			Variance	*SD*		
Participant	0.07	0.27			1752.7	41.87			701.30	26.48		
Residual	0.02	0.13			498.1	22.32			232.50	15.25		
Fixed effects	*β*	*SE*	*t*	*p*	*β*	SE	*t*	*p*	*β*	SE	*t*	*p*
Intercept	2.27	0.08	28.52	<0.001	332.05	12.68	26.19	<0.001	121.61	8.17	14.89	<0.001
Middle phase	−0.04	0.05	−0.89	0.38	9.32	8.44	1.11	0.27	−2.85	5.76	−0.50	0.62
End phase	−0.04	0.05	−0.74	0.46	3.18	8.44	0.38	0.71	−9.69	5.76	−1.68	0.10
Experienced	0.009	0.11	−0.08	0.94	−10.92	17.63	−0.62	0.54	6.79	11.36	0.60	0.55
Student	−0.05	0.11	−0.43	0.67	−14.69	17.36	−0.85	0.40	−6.95	11.18	−0.62	0.54
Middle phase*experienced	0.02	0.07	0.23	0.82	−5.10	11.73	−0.44	0.66	−8.66	8.01	−1.08	0.28
End phase*experienced	0.03	0.07	0.44	0.66	−2.07	11.73	−0.18	0.86	−4.25	8.01	−0.53	0.60
Middle phase*student	0.05	0.07	0.83	0.41	−9.05	11.55	−0.78	0.44	−4.76	7.89	−0.60	0.55
End phase*student	0.14	0.07	2.12	0.04	−20.25	11.55	−1.75	0.08	1.24	7.89	0.16	0.88
Model fit	Marginal R^2		Conditional R^2		Marginal R^2		Conditional R^2		Marginal R^2		Conditional R^2	
	0.01		0.82		0.05		0.79		0.05		0.76	

TABLE 3 Multiple comparisons of means within lesson phases for experience level.

	Fixation count				Fixation duration average				Fixation dispersion average			
	β	SE	*t*	*p*	*β*	SE	t	*p*	*β*	SE	*t*	*p*
Beginning												
Beginner – experienced	−0.009	0.11	−0.08	0.99	10.92	17.6	0.62	0.81	−6.79	11.4	−0.60	0.82
Beginner – preservice	0.05	0.11	0.43	0.90	14.69	17.4	0.85	0.68	6.95	11.2	0.62	0.81
Experienced – preservice	0.06	0.11	0.52	0.86	3.77	17.1	0.22	0.97	13.74	11.0	1.25	0.43
Middle												
Beginner – experienced	−0.02	0.11	−0.22	0.97	16.02	17.6	0.91	0.64	1.87	11.4	0.17	0.99
Beginner – preservice	−0.008	0.11	−0.07	0.99	23.75	17.4	1.37	0.36	11.71	11.2	1.05	0.55
Experienced – preservice	0.02	0.11	0.15	0.99	7.73	17.1	0.45	0.89	9.84	11.0	0.90	0.65
End												
Beginner – experienced	−0.04	0.11	−0.35	0.94	12.99	17.6	0.74	0.74	−2.55	11.4	−0.22	0.97
Beginner – preservice	−0.09	0.11	.-85	0.68	34.95	17.4	2.01	0.12	5.71	11.2	0.51	0.87
Experienced – preservice	−0.05	0.11	−0.50	0.87	21.95	17.1	1.29	0.41	8.26	11.0	0.75	0.73

the visual span in teaching. The broader visual attention observed in experienced teachers during a lesson's early phases could reflect their ability to quickly assimilate and process the classroom environment, drawing from their extensive 'management scripts.' However, as the lesson progresses, their attention might become more selective, reflecting a strategic shift in focus based on classroom needs. This evolving pattern of attention underscores the richness of the teaching process and sets the stage for deeper exploration into understanding the multifaceted influences shaping teachers' visual spans across different classroom scenarios.

According to the third research question, the current study sought to determine whether *the mental effort*, as indicated by the duration of fixations, experienced by teachers during teaching varied with their level of teaching experience. Eye tracking research has shown that the durations of fixations is an indicator for mental effort (e.g., Reingold and Charness, 2005; Van Mierlo et al., 2012; Korbach et al., 2016). However, the concrete relationship in relation to expertise has proven inconsistent across studies (e.g., Gegenfurtner et al., 2011; Jaarsma et al., 2014; Yu et al., 2022). The underlying suggestion is that the connection between expertise and fixation durations could be contingent on the specifics of the task and stimuli (Bertram et al., 2013). In our study's findings, expertise did not yield a significant impact on the average duration of fixations. Interestingly, the data reveals a

TABLE 4 Multiple comparisons of means within experience level for different lesson phases.

	Fixation count				Fixation duration average				Fixation dispersion average			
	β	*SE*	*t*	*p*	*β*	*SE*	t	*p*	*β*	*SE*	*t*	*p*
Preservice												
Beginning – Middle	−0.01	0.05	−0.27	0.96	−0.27	7.89	−0.03	0.99	7.61	5.39	1.41	0.34
Beginning – End	−0.10	0.05	−2.31	0.06	17.07	7.89	2.16	0.08	8.45	5.39	1.57	0.27
Middle - End	−0.09	0.05	−2.05	0.11	17.34	7.89	2.20	0.08	0.84	5.39	0.16	0.99
Beginner												
Beginning – Middle	0.04	0.05	0.89	0.65	−4.22	8.15	−0.52	0.86	2.85	5.76	0.50	0.87
Beginning – End	0.04	0.05	0.74	0.74	−1.11	8.15	−0.14	0.99	9.69	5.76	1.68	0.22
Middle - End	−0.007	0.05	−0.15	0.99	3.11	8.15	0.38	0.92	6.84	5.76	1.19	0.46
Experienced												
Beginning – Middle	0.03	0.05	0.59	0.83	−4.22	8.15	−0.52	0.86	11.52	5.57	2.07	0.10
Beginning – End	0.006	0.05	0.13	0.99	−1.11	8.15	−0.14	0.99	13.94	5.57	2.50	0.04
Middle - End	−0.02	0.05	−0.47	0.89	3.11	8.15	0.38	0.92	2.42	5.57	0.44	0.90

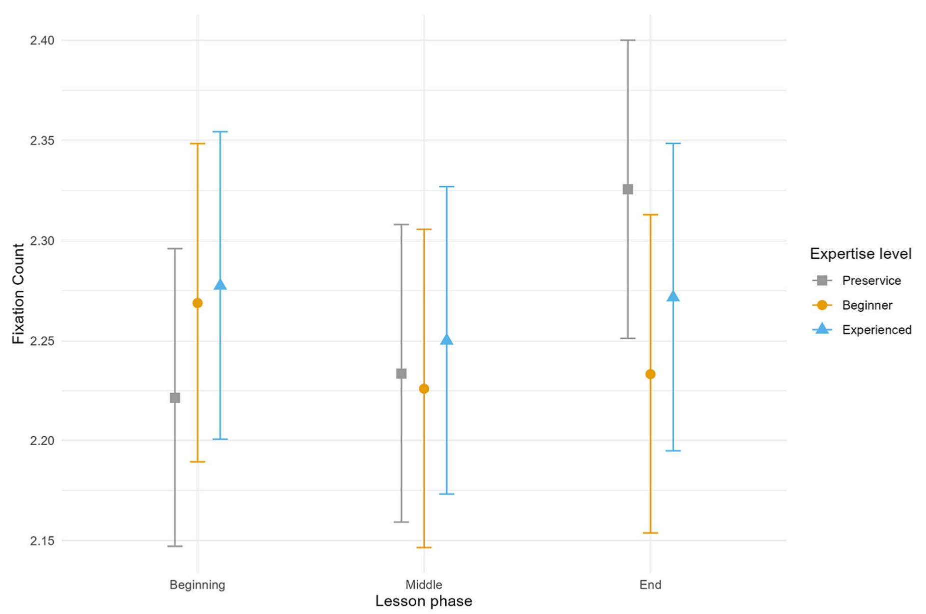

FIGURE 1
Interaction effect of experience level and lesson phase for efficiency of visual processing.

subtle distinction when observing preservice teachers. They manifested a trend towards shorter fixation durations, especially as lessons ended. This trend hints at an increased mental effort for preservice teachers during the concluding segments of lessons. The reasoning might be that preservice teachers still struggle with many aspects of teaching throughout a lesson, such as adhering to a lesson plan, which in turn can result in them experiencing time pressure and stress towards the end of the lesson, which is here reflected in higher mental effort. These insights provide a glimpse into the multifaceted nature of teaching and its cognitive demands, emphasizing the importance of situational context in determining how experience impacts mental effort within the teaching environment.

6.2 Limitations and future research

It is important to note that our results should be interpreted within the limitations of the study. First, the sample size was relatively small, which may have restricted the statistical power to detect subtle differences. Future studies with larger sample sizes could provide more robust insights into the relationship between teaching experience and professional vision. Second, the study focused solely on the count, duration, and dispersion of fixations as an indicator of visual processing efficiency, size of visual span, and mental effort. This approach was chosen (a) because these measures were most appropriate to address our current research questions and (b) due to the sheer amount of data (approx. 217 GB or 45 h of individual

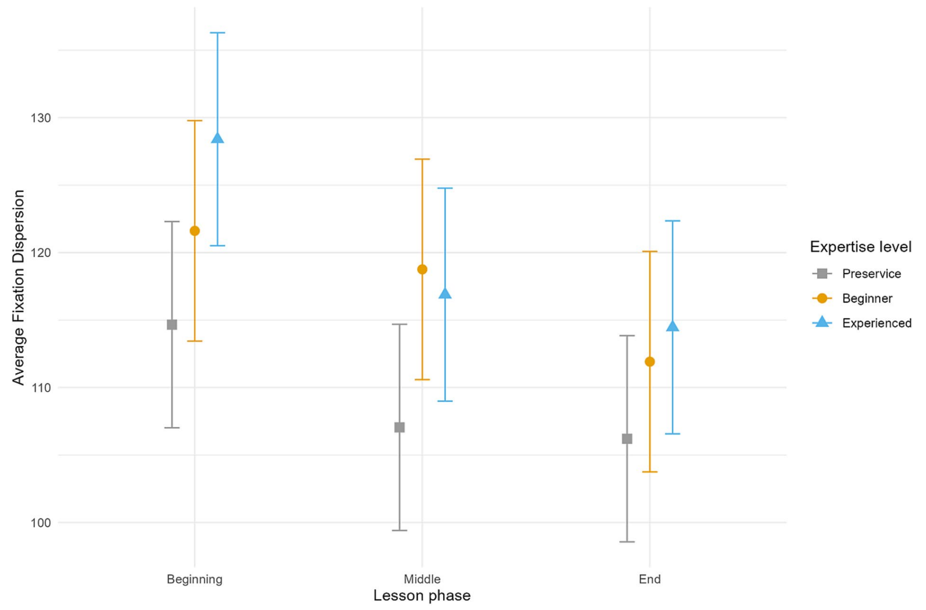

FIGURE 2
Interaction effect of experience level and lesson phase for visual span.

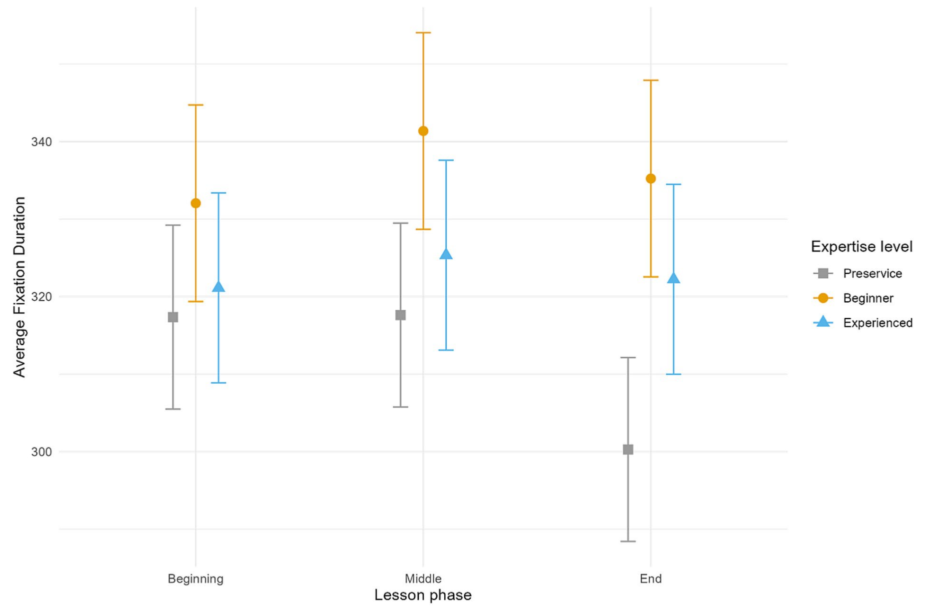

FIGURE 3
Interaction effect of experience level and lesson phase for mental effort.

videos). Other eye tracking measures, such as scan patterns or analyses of specific areas that teachers did or did not look at, could provide a more comprehensive understanding of teachers' visual processing strategies. To be feasible, such analyses require, however, further methodological developments, for instance, on the side of machine learning, or very clear focus on specific moments in the lessons, which analyses as presented in the current study, can provide. Third, we studied teacher groups according to their years of experience in teaching classes. It must be noted, however, that this is not necessarily the same as studying different levels of expertise. Different levels of expertise assume different amounts of knowledge and skills and in particular a clear difference in the advancement of organized knowledge structures in long-term memory (Bromme, 2014; Lachner et al., 2016; Ericsson et al., 2018; Wolff et al., 2021). We can safely assume that preservice teachers have less knowledge and skills compared to the other two groups and even assume that beginning teachers, possess limited experience and thus skills compared to their more experienced counterparts. Where we fall short, however, is the 'experienced' teacher group. Although we know that they have taught for at least 10 years, we cannot guarantee that this made them experts in classroom management. This group could consist of experienced teachers with varying degrees of expertise in classroom management. This fact unfortunately, limits the degree to which we can draw conclusions from our research to the field of expertise studies. Future research should incorporate an assessment of each teacher's level of expertise, for instance, by standardized video-tests (Seidel et al., 2010) or by observing and scoring their classroom management during teaching (Wubbels et al., 2022).

The conflicting findings from previous research and our study highlight the need for further investigation into the relationship between teaching expertise and visual processing. Future research could explore additional factors that may influence visual processing efficiency in teaching, such as pedagogical approaches, subject matter expertise, or classroom management skills. Moreover, incorporating qualitative methods, such as interviews or think-aloud protocols, could provide valuable insights into the cognitive processes underlying teachers' visual attention and information processing.

7 Conclusion

In conclusion, our study did not find overall advantages in the efficiency of teachers' visual processing based on their level of experience alone. Instead, we found an interplay of teaching experience and phase of the lesson indicating that all teachers start off in the lesson in a similar way, but particularly pre-service teachers seem to experience some sort of difficulties with their classroom management as the lesson goes on. Given that classroom management has shown to directly influence pupils' learning and well being (Hattie, 2009), this difficulty could be targeted in teacher training specifically. Eye tracking could serve as a valuable additional information source (next to self-reports and observations) to identify exactly where pre-service teachers face challenges when ending a lesson. For instance, teacher trainers could use such recordings of the individual pre-service teachers to better understand the perspective of the pre-service teacher and provide illustrative feedback on either missed events or incorrectly interpreted ones. These findings contribute to the existing body of literature on experience and visual search, emphasizing the complexity of the relationship in the context of teaching. Further research is needed to unravel the intricate interactions between teaching expertise, visual attention, and cognitive processes to enhance our understanding of effective teaching practices.

Data availability statement

The datasets for this study can be found here: https://osf.io/2ach4/?view_only=6cd13dbe667846babd7f1bd141468df6.

Ethics statement

The studies involving humans were approved by the Research Ethics Committee of the Open Universiteit Nederland (cETO) (reference number U2016/08859/FRO). 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

HJ: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft. SD: Conceptualization, Investigation, Methodology, Writing – review & editing. LC: Data curation, Formal analysis, Writing – review & editing. FC: Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision.

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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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