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Abstract

Effective classroom management is seen as a fundamental component of teachers' professional competence. The early detection of potential disturbances is of great importance for proactive control of the teaching process. Thus, professional vision serves as a link between teacher's knowledge and his or her actions in the event of deviations. Professional vision can be split into two aspects: noticing and reasoning. Previous research, based on subjective test procedures (i.e. video analysis or interviews), has primarily focused on the process of reasoning, whereas only a few studies have focused on the basal process of noticing, i.e. the recognition of possible disturbing situations. It is known from expertise research in different domains using process-based methods, such as eye-tracking, that experts and novices show differences in noticing processes. Therefore, to examine eye-tracking research for the teaching profession – especially noticing in classroom management – a systematic literature search was carried out between the years of 1999 to 2019. A total of 12 studies were found that recorded professional vision in the field of classroom management using eye-tracking. Overall, there were stable differences in the eye movement patterns of experts and novices for different parameters. However, some questions about the indicators used and possible influencing factors on expertise dependent perception remain unsettled.

Keywords

Professional competence; Professional vision; Noticing; Eye-tracking; Gaze behavior; Classroom management

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Ann-Sophie Grub, Antje Biermann & Roland Brünken

Prozessbasierte Erfassung professioneller Wahrnehmung der Klassenführung bei (angehenden) Lehrkräften: Ein systematisches Review

Zusammenfassung

Effektive Klassenführung wird als grundlegender Bestandteil professioneller Kompetenz von Lehrkräften angesehen. Für eine proaktive Steuerung des Unterrichtsgeschehens ist das frühzeitige Erkennen von potentiellen Störungen von großer Bedeutung. Professionelle Wahrnehmung gilt als Bindeglied zwischen Wissen und Handeln der Lehrkraft und kann in die Aspekte Noticing und Reasoning unterteilt werden. Bisherige Arbeiten nutzten häufig subjektive Testverfahren (z.B. Interviews auf Basis von Videostimuli) zur Erfassung des Reasoning-Prozesses. Nur wenige Studien fokussieren auf den basaleren Prozess des Noticing. Aus der Expertiseforschung in unterschiedlichen Domänen, die prozessbasierte Methoden wie Eye-Tracking nutzen, ist bekannt, dass sich Novizen und Experten systematisch in der Erkennung potentieller Störsituationen unterscheiden. Das systematische Review gibt einen Überblick über die Arbeiten, die mit Eye-Tracking-Verfahren den Noticing-Prozess im Bereich der Klassenführung erfasst haben. Dafür wurde eine Literaturrecherche für den Zeitraum von 1999 bis 2019 durchgeführt. Insgesamt konnten 12 Studien identifiziert werden. Es zeigen sich stabile Unterschiede zwischen Experten und Novizen bei den meisten untersuchten Parametern. Sowohl die verwendeten Parameter als auch weitere mögliche Einflussfaktoren auf den Noticing-Prozess werden im Review diskutiert.

Schlagworte

Professionelle Kompetenz; Professionelle Wahrnehmung; Noticing; Eye-Tracking; Blickbewegungen; Klassenführung

1. Introduction

The professional competencies of teachers are the prerequisites for successful teaching, which is positively associated with student learning (Kunter et al., 2013). An important aspect of the multidimensional construct of competence is pedagogical knowledge, especially knowledge pertaining to classroom management (Kunter et al., 2013). This is viewed as a significant requirement for proactive control of the teaching process (Kounin, 2006) and therefore, is vitally important to the performance of students (Piwowar, Thiel, & Ophardt, 2013; Wang, Haertel, & Walberg, 1993). However, to be able to control teaching as proactively as possible, a clear professional vision of the teacher is necessary (cf. Blömeke, Gustafsson, & Shavelson, 2015). This ability describes how individuals observe and interpret events and situations in relation to their profession. Thus, professional vision can be divided into two aspects: noticing and reasoning (cf. Barth, 2017;

Seidel & Stürmer, 2014). The former is the necessary process of recognizing relevant cues, while the latter includes subsequent processes, such as interpreting what has been seen. Hence, the earlier a teacher perceives and anticipates situations relevant to classroom management, the better the proactive control of the teaching process will succeed, which can be summarized under the term "monitoring" (Gold, Hellermann, & Holodynski, 2017). Therefore, good knowledge organization is necessary (Wolff, 2015). Moreover, it is understood from expertise research that this knowledge base is more effectively organized (Wolff, 2015) among experts and thus, also influences perception (Stahnke, Schueler, & Roesken-Winter, 2016). As such, measuring methods for the early recognition of situations, especially for the reasoning process, video analysis, interviews, or questionnaires, have been widely used (cf. Seidel, Blomberg, & Stürmer, 2010). Within the field of expertise research, the eye-tracking method is already used in several domains (e.g. medicine, chess, aviation and traffic psychology) to capture cognitive perception processes (e.g. Gegenfurtner, Lehtinen, & Säljö, 2011), and can be harnessed to assess the noticing process in observing classroom management (e.g. Stürmer, Seidel, Müller, Häusler, & Cortina, 2017; van den Bogert, 2016). The use of this method has some advantages in comparison to verbal methods. At first, the recording of eye movements allows conclusions about the attention processes of the participants, which normally take place unconsciously and therefore, are difficult to verbalize (e.g. van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009). Additionally, eye-tracking integrates both spatial and temporal information (Wolff, 2015), whereas with other methods, the focus can only be on one of these two tiers. To summarize, the advantage of eye-tracking can be seen in the direct and objective assessment of visual processing (cf. Wolff, 2015). It is also known from various domains, e.g. medicine, that these cognitive measures of behavior measurement are sensitive to differences in expertise (e.g. Gegenfurtner et al., 2011). Since eye-tracking methods offer the possibility to measure especially the basal ability of noticing (Riedl, Brandstätter, & Roithmayr, 2008), this paper presents an overview of different indicators of gaze behavior that can be used to capture differences in expertise. Moreover, the suitability of various indicators for measuring the professional vision of teachers in the field of classroom management is discussed.

2. Theoretical background

2.1 Professional competence

Teaching is a complex system characterized by multidimensionality, simultaneity, immediacy and unpredictability (Doyle, 1980). Accordingly, the high demands placed on teachers are also multifaceted. Therefore, research in the field of teaching emphasizes the importance of teacher competence; thus, the professional competence of teachers is a multidimensional construct (Blömeke et al., 2015). Competence is assumed to be a continuum consisting of three components: the foundation is cognitive (e.g. professional knowledge, cf. Blömeke et al., 2015; Casale, Strauß, Hennemann, & König, 2016) and affective-motivational dispositions (e.g. aim of a broad activation of a learning group, cf. Blömeke et al., 2015; Casale et al., 2016). These dispositions influence the perception, as well as the interpretation of situations and the resulting decisions. Knowledge about classroom management as part of the generic dimension of pedagogical knowledge affects the ability to perceive and anticipate potential disruptive behavior and thus, the organization of disturbance-free lessons (Wolff, 2015). Especially for novice teachers, it is often a challenge to perceive all critical moments and to show effective handling of imminent or occurring disorders due to multidimensionality, as well as the simultaneity of interactions and events in the classroom and the need for immediacy of reactions (Wolff, 2015).

2.2 Classroom management

The basis for effective classroom management is the smooth organization of all activities in the classroom and to avoid interruptions and misconduct to maximize the time for teaching and learning (Emmer & Stough, 2001; Kounin, 2006; Steffensky, Gold, Holodynski, & Moeller, 2015). Therefore, visual monitoring and scanning of the classroom are of high importance (Gold & Holodynski, 2017). With the terms "withitness" and "overlapping," Kounin (2006) identified two skills that are particularly crucial for professional perception. Withitness describes the ability of a teacher to be informed at all times about what is happening in the classroom (cf. multidimensionality, Doyle, 1985). To manage the classroom adequately and effectively, a precise detection and observation of relevant cues and events is required (van den Bogert, van Bruggen, Kostons, & Jochems, 2014; Wolff, 2015). Overlapping means that the teacher is able to deal with different issues at the same time, e.g. flow of instruction and some unavoidable disciplinary problems (cf. simultaneity; Doyle, 1985) to react appropriately to the situation (cf. immediacy; Doyle, 1985). Both abilities are dependent on constant visual attention processes (van den Bogert et al., 2014). The dimensions of withitness and overlapping can be summarized under the term "monitoring" (Gold & Holodynski, 2017). Thus, monitoring is a process that encompasses the teachers' awareness of all relevant and simultaneously operating processes in the classroom, as well as the demonstration of such awareness to students (Gold & Holodynski, 2017). Therefore, perception, especially monitoring, should be a key component of any teacher because early detection of any student disturbances and the awareness of what is happening in the classroom are relevant factors for classroom management (van den Bogert et al., 2014).

2.3 Professional vision

There are several models to explain perception within the professional context (Endsley, 1995; Goodwin, 1994; Seidel et al., 2010; Seidel & Stürmer, 2014; Sherin, 2001). Two modeling approaches (situation awareness; Endsley, 1995, and professional vision; Sherin, 2001) focus on the perception process in a professional context, especially in teaching. Both models of professional vision describe the process of perception with sub-processes. Endsley (1995), in the model of *situation awareness,* describes three sub-processes ("perception," "comprehension," and "anticipation" to further events). This model originated from the domain of dynamic human decision-making systems and can be applied to the domain of teaching (Barth, 2017). The three levels are built upon each other and it is assumed that the level of difficulty in mastering each level increases from level 1 to level 3. As such, the perception of relevant situations is influenced through individual (e.g. experience, ability) and environmental factors (e.g. complexity, stress). *Professional vision* is a concept derived from Goodwin (1994) and adapted by Sherin (2001). The process of professional vision can also be divided into three sub-processes ("identification," "making connections," and "reasoning"), which many authors summarize into two main processes, including "noticing" ("identification") and "knowledge-based reasoning" (summarizing "making connections" and "reasoning") (e.g. Barth, 2017; Seidel et al., 2010; Seidel & Stürmer, 2014). Noticing describes the ability to focus attention on situations that are relevant for teaching and learning, whereas knowledge-based reasoning describes the ability to apply knowledge about teaching and learning and to draw appropriate conclusions. This process can be seen as an indicator of the quality of the application of knowledge to the situation in the classroom. Noticing and knowledge-based reasoning interact with each other (Sherin, 2007). Another similarity of the two models is that the process of identifying relevant cues or events is seen as the necessary process of professional vision. Without this inevitable process of noticing, processes of reasoning based on it cannot take place. In the following, the term "professional vision" will be used throughout, as this is the more common term in education research (c.f. Barth, 2017; Gold & Holodynski, 2017).

The competence model of Blömeke et al. (2015) also ascribes a unique role to perception because this process represents an essential basis for situation-specific skills. The interpretation of situations and the relevant cues and decision-making is possible only on the basis of perception. Therefore, noticing represents an unavoidable step in the perception of aspects of teaching relevant to classroom management.

2.4 Expertise

Expertise differences can be found in various domains, such as aviation, chess, and medicine, as well as in education (Gegenfurtner et al., 2011; Gegenfurtner & Seppänen, 2013; Reingold & Sheridan, 2011; Stahnke et al., 2016; van der Gijp et al., 2017). For example, Housner & Griffey (1985) found expertise differences in terms of classroom perception. According to Berliner (2001), expertise is domain specific. That is, knowledge is better structured by experts in the specific domain than by novices. Problems are represented in qualitatively different ways than by novices so that experts can remember meaningful schemata faster, e.g. experienced teachers are expected to process information faster and thus, need less time to comprehend a classroom situation (Chi & Glaser, 1988). Besides, experts are flexible and opportunistic planners who can change representations faster. In contrast, novices are more rigid in their concepts. Furthermore, experts are able to interpret ambiguous stimuli, while novices are more easily deceived. Thus, it can be summed up that experts tend to steer "top-down," while novices tend to be subject to "bottom-up" cognitive processes (Hershler & Hochstein, 2009). Also, Livingston and Borko (1989) claim that the distinction between expert and novice teachers occurs in the flexibility of cognitive schemata. Similarly, the model by Wolff (2015) describes the influence of knowledge ("classroom management scripts") on expert and novice teachers' perceptions, awareness and interpretative processing of problematic classroom situations. It has been found that teachers' knowledge organization affects the perceptions of classroom situations and ensuing situational awareness.

To distinguish experienced teachers from novice teachers, the criteria of Palmer, Stough, Burdenski, and Gonzales (2005) can be used. Palmer et al. (2005) postulated that experts should be selected by years of experience (a minimum of three to five years), social recognition (two or more different socially recognized persons from the corresponding domain), professional or social group membership, and performance-based criteria (e.g. student achievement).

To measure differences in expertise in the visual perception of situations relevant for classroom management, process-based methods are particularly suitable. This unique appropriateness results from the fact that visual perception is a continuous process. Over recent years, eye-tracking has become an important tool to investigate such processes (Holmqvist et al., 2011) because most information is processed through the eyes and these sensory organs are therefore ascribed a special role in the process of visual perception (in particular, information reception and processing) (Jarodzka, Holmqvist, & Gruber, 2017).

2.5 Acquisition of professional vision

Research on teacher expertise often uses high inference or subjective measurement methods because findings often rely on the interpretation of, for example, traditional observational data, video analysis, or interviews (Cortina, Miller, McKenzie, & Epstein, 2015). In a study from Wolff, van den Bogert, Jarodzka, and Boshuizen (2015), participants were encouraged to describe short video vignettes regarding classroom management, while Carter, Cushing, Sabers, Stein, and Berliner (1988) used photographic slides from classrooms, urging participants to describe and provide a reconstruction of the situation. In a study of Huang and Li (2012), the participants were asked to describe two lessons and then make suggestions for improvement and an evaluation of the watched lessons.

These studies could uncover differences between experts and novices in their perception and interpretation of situations relevant for classroom management on the reasoning level; however, these studies could not make a prediction about exactly which visual attention processes are responsible for these differences. Expertise research of different domains (medicine, chess, etc.), on the other hand, are traditionally based on low-inference objective measures (such as the measure of gaze movements) as an indicator of cognitive functions (van Gog et al., 2009). Eye-tracking has long been used to investigate selection and attention patterns (Bucher & Schumacher, 2012) and to obtain online measures of cognitive processes (Lachner, Jarodzka, & Nückles, 2016). This allows gaze movements to be used as behavioral indicators for cognitive processes (e.g. eye fixation data reflect attention and shifts in attention, cf. van Gog et al., 2009). As such, eye-tracking offers the possibility to investigate teachers' basic perceptual processes on the noticing level (Wolff, Jarodzka, van den Bogert, & Boshuizen, 2016).

2.6 Parameter/Indicators of professional vision

To assess professional vision with the eye-tracking method, several indicators are worth considering. According to the oculomotor definition, a fixation describes the period of time in which the eye behaves relatively motionless, i.e. moves as little as possible (Holmqvist et al., 2011). In general, fixations are an indicator, such as which environmental areas are allocated with attention and from which areas information is received or rather which stimuli are important (Just & Carpenter, 1976). Thus, the degree of experience influences the *number of fixations* (also called fixation density). Experts have more fixations on relevant areas in their specific domain, such as aviation (Kasarskis, Stehwien, Hickox, Aretz, & Wickens, 2001), as well as dynamic stimuli (Jarodzka, Scheiter, Gerjets, & van Gog, 2010). This indicates that experts use their elaborated schemata while perceiving scenes, including school lessons. Teaching experts have theories about how to recognize potential disorders early and fixate exactly these areas more often (e.g. students who are not attentive or play with extra-curricular teaching materials). *Fixation dura-*

tion describes the period of time that a fixation continues and is likely to be the most used measure in eye-tracking research (Holmqvist et al., 2011). Jarodzka et al. (2010) demonstrated that novices have longer mean viewing times than experts. This implies that experts are faster in encoding information due to their professional knowledge (Chi & Glaser, 1988), which allows individuals with higher expertise to plan ahead in dynamic situations (cf. Jarodzka et al., 2017). Based on these eye movement parameters (many and short fixations), dynamic classroom situations can be updated permanently ("Like circus performers who keep plates spinning on top of sticks, teachers must not only establish a management system that works but keep it working by monitoring events continually and responding when breakdowns occur.", Brophy, 1988, p. 3). Another measure is the *distribution of fixations*. In general, the distribution of fixations can be an indicator for deeper cognitive processing or the importance of a region (Kuperman, Bertram, & Baayen, 2008; Reingold, Charness, Pomplun, & Stampe, 2001), which leads to a relatively longer fixation time for relevant regions for experts in a domain. Regarding monitoring behavior or the awareness of what is going on in the classroom, the distribution of attention across students should be more evenly placed for expert teachers (Wolff, 2015).

In the context of monitoring, two further parameters can be used: *revisits* and *fixation skips*. Repeated fixations respectively revisits give insight about gathered and updated information (cf. Wolff, 2015). Through the analysis of areas in which people look back, conclusions can be drawn about which areas are classified as relevant by the person, whereas fixation skips highlighted areas, which are ignored from viewers. This can also be used to identify which areas, for example for experts, are classified as rather irrelevant due to their knowledge and are therefore visually skipped, and which areas, in contrast, are particularly relevant and are therefore reviewed permanently again and again.

When interpreting eye movements as a method for recording underlying cognitive processes, some assumptions are often made implicitly or explicitly (Rötting, 2001). According to Just and Carpenter (1980), for example, it is assumed that there is no appreciable lag between what is fixed and what is processed (eye-mind-assumption). This variant of interpretation has been criticized for a long time (e.g. Ehrlich & Rayner, 1983). The interpretation of the parameters and the use of the parameters as indicators should therefore in principle be done on a theoretical basis and never on the basis of a measure alone (cf. Murray, Fischer, & Tatler, 2013).

The aim of the study is to provide an overview of the current research on the process-based indicators used thus far to record professional vision among experts and novices in the field of classroom management.

3. Method

A systematic review (van Wee & Banister, 2016) of the literature from 1999 until 2019 was performed by using three databases, including ERIC, PsycINFO and the Web of Science. At first, the databases were searched by using different combinations of relevant keywords included in the full text of the article. Those keywords included expertise, teach, classroom management and eye-tracking, as well as related words and synonyms (a comprehensive list of search strings is attached in the Appendix, Table A). To minimize publication bias, not only different databases were used, but search restrictions (e.g. peer review procedures) were also dispensed with (cf. Zawacki-Richter, Kerres, Bedenlier, Bond & Buntis, 2020). This search revealed a sample of 1,178 papers after the elimination of duplicates. To be included in the database, during a second step, the studies needed to contain the examination of the perception of classroom management from (pre-service) teachers through process-based measurements. Therefore, all papers were excluded whose title and abstract content did not coincide with the research topic. This resulted in 29 articles, which were examined more closely by two reviewers during a third step. Thereafter, all papers were excluded whose content did not coincide with the research topic and in particular, the process-based acquisition of perception, resulting in a total of eight papers. In the last step, all remaining papers were cross-referenced, which led to three additional articles. In total, the database search and cross-references identified 11 articles with 12 studies that were included in the review. Thereof, three studies came from doctoral theses, which have not yet been published in peer-review journals (a graphical representation of the complete process can be found in Appendix, Figure A). For a more detailed analysis, information on the sample, the selection criteria of experts and novices, stimuli, as well as the eye-tracking method used were extracted in Table 1. Moreover, the parameters used to assess professional vision and their indication in classroom management were extracted to analyze them more precisely in the results chapter (see Table 2).

4. Results

4.1 Methods and equipment

We found eight studies using a real world classroom with mobile eye-tracking (1, 2, 3, 4, 5, 6, 11, and 12; see Table 1), and four studies using videos from lessons as study materials with a static eye-tracker (7, 8, 9, and 10; see Table 1). Eye-tracking records in real classrooms have durations between 10 and 45 minutes. However, eye-tracking records in a laboratory setting were based on different numbers of videos (1 to 8) and different duration times (about 2 to 4 minutes).

Table 1: Descriptive description

	Author (year)	Method	Stimulus	Sample (N)		Expertise criteria	
				E	N	E	N
1	Cortina et al. (2015)	Mobile eye-tracking	Real classroom	12	12	– Mentors	– Mentees
2	Dessus, Cosnefroy, & Luengo (2016)	Mobile eye-tracking	Real classroom	2	2	– 20 and 25 years teaching experience	– 0.5 years teaching experience
3	McIntyre & Foulsham (2018)	Mobile eye-tracking	Real classroom	20	20	– At least 6 years' experience, – Social nomination, – Professional membership, – Performance rating	– Teachers in the same school who contrasted most with the expertise criteria
4	McIntyre, Jarodzka, & Klassen (2017)	Mobile eye-tracking	Real classroom	20	20	– cf. McIntyre & Foulsham (2018)	– cf. McIntyre & Foulsham (2018)
5	McIntyre, Mainhard, & Klassen (2017)	Mobile eye-tracking	Real classroom	20	20	– cf. McIntyre & Foulsham (2018)	– cf. McIntyre & Foulsham (2018)
6	Stürmer et al. (2017)	Mobile eye-tracking	M-Teach situations	/	7	– /	– Preservice teachers
			Real classroom		4	– /	– /
7	van den Bogert et al. (2014)	Eye-tracking	Videos from real life classrooms	7	7	– Selected by three teacher-supervisors – 10 years of experience teaching, – Possess a keen understanding of what goes on in their classrooms, – Are known to create and maintain a positive learning climate	– Randomly selected from first and second year student teachers

Table 1 continued

Table 1 continued

	Author (year)	Method	Stimulus	Sample (*N*)		Expertise criteria	
				E	N	E	N
8	van den Bogert (2016)	Eye-tracking	Videos from real life classrooms	34	32	– cf. van den Bogert et al. (2014)	– First and second year student teachers, – 10-40 hours of teaching experience
9	Wolff, Jarodzka, van den Bogert, & Boshuizen (2016)	Eye-tracking	Videos from real life classrooms	35	32	– 7 years teaching experience, – Recognized by fellow teachers as a competent or above-average classroom manager, – Recommended by their school leaders as experts in teaching profession	– First or second year of teacher training, – 10-40 hours of classroom teaching experience
10	Yamamoto & Imai-Matsumura (2013)	Eye-tracking	Video from real life classroom	43	/	– From in-service teacher training, – 15.7 years, SD = 8.7 teaching experience	– /
11	Huang (2018)	Mobile eye-tracking	Real classroom	25	25	– Experienced teachers	– Mentees
12	Huang (2018)	Mobile eye-tracking	Real classroom	10	/	– /	– /

Note. E = experts, N = novices.

4.2 Sample

Eight of the studies compared the gaze behavior between expert and novice teachers (1, 2, 3, 4, 5, 7, 8, 9, and 11; see Table 1). Concerning the selection criteria of the experts and novices, different levels of detail were given in the studies. Studies 1, 11, and 12 described experts simply as mentors or experienced teachers and the novices as mentees but did not provide any information on teaching experience. Contrary, the other studies (2, 3, 4, 5, 7, 8, and 9) used the length of teaching experience as a criterion for distinguishing between experts and novices; thus, experts had a minimum of six years of experience. Novices, on the other hand, had only 0.5 years or 10-40 hours of teaching experience. Multiple studies used further criteria to distinguish between experts and novices (3, 4, 5, 7, and 9), such as social nomination or classroom management performance. In Study 10, the length of teaching experience was used as a continuous variable, but no novices were included. In Study 6, only novice teachers were included, while in Study 12, only expert teachers attended, teaching different subjects. Both studies gave critical insights into cognitive structure and possible influencing factors beyond the expertise of teachers' gaze and therefore, were included in the review.

4.3 Parameter and results

4.3.1 Number of fixations

Five of the 12 analyzed studies used the parameter "number of fixation," while Study 7 revealed more overall fixations for expert teachers (see Table 2). Studies 8 and 11 focused on relevant (e.g. disorderly behavior of students, instructional material) vs. irrelevant areas, and both studies showed that both groups had a comparable total number of fixations, such as in Study 7. However, the results from Studies 7, 8 and 11 also showed that experts have more fixations these relevant areas more often than novices. Results from Study 10 (only expert teachers) displayed that teachers fixated on the disturbing students more often when they were aware of them than when they were not. Unexpectedly, the aware teachers did not have longer teaching experience than the unaware teachers, which eventually was explained with a problematic operationalization of disturbing behavior in the study (see also Wolff et al., 2016). Study 6 (only novices) demonstrated that the participants mostly looked at the students, followed by the instructional material.

In conclusion, the three studies with the expert-novice-comparison, indicate that experts have more fixations than novices, especially on relevant areas or rather, students in the classroom, which give first insights, that the assumptions can be confirmed with the eye-tracking method, too. Further, the results of Study 6 indicate that novices focus mostly on students and may be aware of the relative importance of students as cues for effective classroom management.

4.3.2 Fixation duration

Eight studies used the parameter “fixation duration” (see Table 2). Results from Study 7 and 11 revealed that experts have overall shorter fixation durations compared to novices; however, in Study 8, only with a more fine-grained expertise-classification with four expert groups could differences be seen between an inverse U-shaped relationship for fixation duration. Thus, conclusions from these studies indicated, that by the use of eye-tracking, results can be achieved which correspond to the assumptions, such as fixation duration can be seen as an indicator of the fast encoding processes by experts (Chi & Glaser, 1988). Results from Study 5 indicated that experts have longer durations directed at students compared with novices. Contrary, novices had longer durations on non-student areas than experts. The outcomes of Study 2 using gazing time showed that every teacher looked at every student a few times but experts in this study focused longer on less abled students (in terms of behavior) than novices. Study 8 found no differences in the total dwell time regarding disruptive students between the expert groups (focus on length of dwell time). A possible explanation for this is the high salience of these pupils in the selected scenes. Participants looked longer at the students, followed by the instructional material; nevertheless, in Study 10, the teachers who were aware of the disturbing students watched the troublemakers longer than the other students. These results are also in line with the assumption of deeper processing by focusing on essential areas (Kuperman et al., 2008; Reingold et al., 2001). When looking at different subjects taught by the same teacher (Study 12), the observed fixation duration on students was longer when teaching literacy compared to math. This implies that this indicator not only depends on expertise but also on the issues and goals of the specific subject.

4.3.3 Fixation dispersion

Ten studies used this relative parameter with different measures (see Table 2): Gini-coefficient (1 & 2), gaze proportion (4 & 5), ranked scores of total fixation frequency and fixation duration (6 & 7), total dwell time (8, focus on dispersion of dwell time), fixation dispersion average (9), standard distance deviation (11) and Gaussian density plot (12). Studies 1, 2, 6, and 7 investigated distribution across different students in a classroom as an aspect for monitoring behavior. Studies 4, 5, 8, 9, 11 and 12 were more interested in the distribution of the gaze behavior across more didactical aspects in the classroom (e.g. learners in relation to instructional material) as an indicator for their relevance regarding instruction, especially classroom management. In general, results from the first mentioned studies indicate that experts scatter their view more evenly across students; that is, that they show better monitoring behavior. However, two of these studies resulted in a more differentiated look. Study 2 also assessed information from students regarding their behavior and their academic achievement. At a descriptive level, the authors could show that experts searched for more information regarding students with problematic behaviors in relation to other students, while novices distributed their attention more evenly across students. In Study 6, the novices taught a class with four students with defined roles (cf. struggling, uninterested). Overall, for novice teachers, the distribution over the four students was relatively even but the results also show strong interindividual differences between teachers.

Regarding distribution over didactical events, the results of Study 4 show that experts look more frequently at relevant aspects (e.g. students) in comparison to other didactical aspects (like instructional material) or irrelevant stimuli, while novices distributed their attention more evenly across non-instructional material and students (focus on distribution of gaze behavior). Study 9 also showed that experts were more focused when taking an overall distribution of fixations into account. In contrast, in Study 11, the dispersion was higher for experts. Unfortunately, the authors of both studies gave no deeper insights about the precise content of the focus. However, Study 12 further takes into account that interpretation of the fixation dispersion not only depends on the analytical unit (cf. distribution over students or over didactical aspects) but also on different instructional aims in different subjects. In regard to literacy, the focus remained more on students, whereas in math, the focus was set more on instructional material, such as the blackboard, relative to the other elements.

4.3.4 Skips and revisits

Only Study 9 examined the skips in eye-movement behavior (see Table 2). Descriptive results suggested that novices skipped more areas than experts, though the authors found no statistical interference confirmation. Studies 5 and 9 engaged with revisits as an indicator for monitoring, while results from Study 9 demonstrated that experts revisited more areas than novices when observing classroom scenes. Thus, it appears that experts searched for activity between students, as well as following posture and body movements. Results from Study 5 supported these findings, along with shorter return times to relevant attractors for experts.

4.3.5 Others

Some studies used further parameters to examine eye-movement behavior (see Table 2). For example, Study 3 applied a string based scanpath analysis, which preserves information about what and in which order the participants looked, as well as what could be seen as a reflection about the internal representations of the teachers. Due to a shared structure of professional knowledge, the internal model and scanpaths of experts should be equal compared with novices. In line with this assumption, the gaze behavior of different teachers at one level of expertise is more similar than the gaze behavior of different teachers at various levels of expertise.

Table 2: Methodological description

	Author (year)	Parameter	Indicator for	Hypothesis	Confirmation
1	Cortina et al. (2015)	GINI-coefficient	Monitoring	E < N	Y
2	Dessus, Cosnefroy, & Luengo (2016)	GINI-coefficient	Monitoring	E > N	Y
		Gazing time	Attention	E > N	Y
3	McIntyre & Foulsham (2018)	Scanpath	Monitoring	ΔE < ΔN	Y
4	McIntyre, Jarodzka, & Klassen (2017)	Gaze proportion	Attention	E > N	Y
5	McIntyre, Mainhard, & Klassen (2017)	Gaze duration	Cognitive processes	E > N	Y
		Return times	Efficiency	E > N	Y
		Gaze flexibility	Monitoring	E > N	Y
6	Stürmer et al. (2017) (only N)	Number of fixation	Attention	High σ	Y
		Fixation duration	Attention	High σ	Y
		Switchover	Attention	High σ	Y
		Ranked scores of total fixation frequency	Monitoring	High σ	Y
7	van den Bogert et al. (2014)	Mean fixation duration	Processing time	E < N	Y
		Mean fixation count	Monitoring	E > N	Y
		Total time fixation duration scores	Monitoring	ΔE < ΔN	Y
8	van den Bogert (2016)	Mean fixation duration	Processing time	E < N	N (2 groups) Y (4 groups)
		Total dwell time	Divide attention between one salient event and the rest of the classroom	E < N	N (E ≙ N)
		Scanpath length	Monitoring	E > N	Y

Table 2 continued

Table 2 continued

	Author (year)	Parameter	Indicator for	Hypothesis	Confirmation
		Number of visits	Monitoring	E > N	Y
9	Wolff, Jarodzka, van den Bogert, & Boshuizen (2016)	Fixation dispersion average	Monitoring	E ≟ N	Y (E > N)
		Number of revisits	Gather and update information	E ≟ N	Relevant areas: E > N
		Number of skips	Ignored classroom information	E ≟ N	N (E = N)
10	Yamamoto & Imai-Matsumura (2013) (only E)	Fixation count	Awareness	A ≠ UA	Y (A > UA)
		Fixation length	Awareness	A ≠ UA	Y (A > UA)
		Mean fixation duration	Awareness	A ≠ UA	N (A ≙ UA)
		Time to first fixation	Awareness	A ≠ UA	N (A ≙ UA)
11	Huang (2018) Study 1	Distribution of fixations	Attention	E > N	Y
		Fixation duration	Attention	E < N	Y
		Fixation count	Monitoring	E > N	Y
		Saccade amplitude	Monitoring	/	E > N
		Saccade direction	Monitoring	/	E ≠ N
12	Huang (2018) Study 2 (only E)	Distribution of fixations	Attention	/	Math = literacy
		Fixation duration	Monitoring	/	On students: literacy > math
		Fixation count	Monitoring	/	On students: literacy > math

Note. E = experts, N = novices, A = aware teachers, UA = unaware teachers.

Study 8 used scanpath length, which is defined according to Holmqvist et al. (2011) as the sum of all saccadic amplitudes in a scanpath. The study found a positive linear relationship between the level of expertise and scanpath length, which can be interpreted as a broader monitoring behavior for experts. In Study 5, the authors used a state space grid-method to examine gaze behavior on a more didactical level. With this method, the authors could define a so-called "efficient didactical gaze" (the most stable and prevalent gaze behavior) and calculated the return time to this gaze for experts and novices. Results showed that experts returned faster to the efficient gaze. Moreover, the authors measured the flexibility of gaze behavior regarding various instructional aims and showed that experts adapted their gaze behavior. That is, experts had different amounts of transitions between student and non-student areas depending on their aims (transmit information to students vs. gain information about students).

5. Discussion

This review aimed to systematize the current research in the field of professional vision among experts and/or novices regarding classroom management measured with eye-tracking. Based on a literature search, 12 studies have been included and described concerning the used indicators, their sensitivity to expertise differences, and further influencing factors.

5.1 Methods

The included studies differ regarding the applied stimuli and their standardization. Several studies presented videos of school lessons relying on high controllability and standardization, while other studies preferred higher external validity through the use of mobile eye-tracking in real classrooms. Results from Foulsham, Walker, and Kingstone (2011) suggest that eye-tracking data from the real world in comparison to data from videos differ at some points. For example, the condition of the real world allows a head turn and thus, the natural freedom of movement. Furthermore, real classrooms differ in many aspects, which makes comparisons more complicated, including the composition of students, the arrangement of the material elements, and the general learning situation. Some of the studies with real classrooms increased the standardization at some points; for instance, Study 6 used a highly standardized simulated situation with the same students being given roles. In Study 11, the respective pairs (mentors & mentees) taught the same students with the same topic in the same classroom, while in Study 12, the same teacher taught two subjects in the same class. Nevertheless, systematic differences in the expertise of eye-movement behavior could be uncovered both in a real world classroom and in a laboratory setting.

Furthermore, the use of various eye-tracking devices and different technical features can present an influencing variable on the sensitivity of the measurements (in the analyzed studies e.g. different sampling rates with a range from 30 Hz to 250 Hz were used). However, differences in expertise in gaze behavior were found across all studies, which suggests that this behavior differs between experts and novices and that the eye-tracking procedure is sensitive to these differences.

5.2 Sample characteristics

Several of the studies with an expert-novice-paradigm distinguished experts and novices only on the basis of years of experience, while other studies applied at least one other criterion postulated by Palmer et al. (2005). These factors included social recognition, professional or social group membership, though only for experts. This can be problematic in several ways, as some novice teachers can have a well-developed professional vision (cf. due to former experience with students or children, see Studies 7 and 8). Moreover, those deemed expert teachers based only on their years of experience may not necessarily be good perceivers (see Study 10; also Palmer et al., 2005). Thus, studies should apply the criterions by Palmer et al. (2005) and control professional knowledge for the investigated aspects of professional vision (cf. Lachner et al., 2016).

Furthermore, it should be kept in mind that the sample size of some of the included studies were relatively small with limited power for inferential statistics.

5.3 Differences in parameter used and their sensitivity to expertise

Two of the parameters most commonly used in the papers were "number of fixations" and "fixation duration." It was found that generally, experts have more, but shorter fixations, whereas novices have less, but longer fixations. This is in line with the assumption of fast encoding processes by various experts (Chi & Glaser, 1988). Specifically, experts fixated relevant areas (e.g. disruptive students) more often and for a longer duration than irrelevant areas (e.g. non-instructional material) compared to novices, who looked more frequently at irrelevant areas. These results confirm deeper cognitive processes by focusing on important areas (Kuperman et al., 2008; Reingold et al., 2001). However, mere eye movement data should always be interpreted with caution (see the section of further implications).

In almost all included studies, parameters were used to measure attention distribution but with different indicators (e.g. Gini-coefficient, difference coefficients, fixation duration, and fixation frequency). These parameters are useful to assess monitoring behavior or to assess the relevance of one student in a group of students (e.g. a disruptive student) or didactical objects regarding the teaching situation (e.g. learners vs. instructional material). It was found that experts distributed their attention more evenly over students and spent, on average, less time with single area of interest (AOI). This result can be combined with the results of the number of fixations and fixation duration, as fast and short fixations allow permanent and fast scanning of the classroom. This ability to monitor has also been recorded e.g. utilizing previously fixed AOIs. This reveals that experts return more frequently to relevant areas and therefore, can regularly update their internal information about what is happening throughout the classroom. Furthermore, scanpath comparisons indicate that more experienced teachers look around more frequently in the classroom, i.e. experts scan the classroom more actively than novices. This result also matches the expertise-dependent observation behavior of monitoring (cf. Brophy, 1988; Carter et al., 1988).

Using dispersion measures often entails the problem of inappropriate aggregation of data (Orquin & Holmqvist, 2018). A stronger focus on one area in relation to another may first be due to higher relevance recognized by top-down processes (cf. Orquin & Mueller Loose, 2013), second due to the complexity of the object (Just & Carpenter, 1976), or third due to its saliency (bottom-up processes, Itti & Koch, 2001). To this end, it is important that a description of the meaning (e.g. students, student material) and of the relevance of the AIOs for the teaching process is of great importance for interpreting the data. This process should not only be made data-driven (a relevant AOI is one that experts focus on more often and for longer periods of time), but also normatively by the researcher or both regarding a special teaching situation (see also the next section on implications for further research).

However, there are also limitations regarding the expertise-sensitivity of the eye-tracking parameters in the context of professional vision. Five of the included studies (3, 4, 5, 10, and 12) concluded that expertise is not the only influence on teachers' visual processing but also their cultural background or the subject. Thus, it is known that the cognitive models of teachers depend on shared culture (Blömeke, Olsen, & Suhl, 2016; Hofstede, 1986). However, didactical strategies and the teachers' gaze behavior or the relevance of stimuli depend on the aims of the subject (König, Blömeke, Paine, Schmidt, & Hsieh, 2011). According to the Endsley's model of situation awareness (1995), besides expertise, for example, stress (e.g. Sneddon, Mearns, & Flin, 2013), cognitive load (e.g. Dessus, Cosnefroy, & Luengo, 2016; Prieto, Wen, Caballero, Sharma, & Dillenbourg, 2014) or task characteristics (e.g. Gegenfurtner et al., 2011; Yarbus, 1967) represent influencing variables during the perception process.

5.4 Implications for further research

Over the past decade, eye-tracking has become increasingly popular as a method for educational research. In turn, the equipment needed to study this method has become cheaper, while the handling has become easier (Orquin & Holmqvist, 2018). As a consequence, many test subjects can be collected with relatively little effort, making it possible to develop more complex designs with several comparison groups that still have sufficient power.

One question on the definition of expertise is at what point professional vision starts to develop and if the development of professional vision is similar to the five-stage model of expertise acquisition postulated by Dreyfus (2004). Thus, the use of these intermediate stages of expertise development in relation to professional vision could possibly explain the inverse U-shaped connection found by van den Bogert (2016).

Potentially, the use of standardized videos or scenarios would be a suitable method for future studies to experimentally manipulate the extent of the complexity caused by classroom management events. It could be investigated whether the differences in expertise are expressed differently depending on the number and integrity of events in the classroom (cf. Wolff et al., 2016). Contrasting videos with situations relevant for classroom management without such situations could also provide information on whether, and if so, the gaze behavior of experts and novices relates to classrooms without disturbing elements.

With regard to the method of eye-tracking, there are also limitations, with regard to the evaluation and interpretation of the parameters. The eye-mind-assumption (Just & Carpenter, 1980) states that eye fixations are directly linked to attention processes. Shifts in fixation are therefore also directly linked to shifts in attention (Holmqvist et al., 2011). It is generally assumed that a person who fixates on a particular point also processes information contained in that point simultaneously. However, this assumption does not take into account, for example, hidden attention (Posner, 1980): It is possible to look at a point, i.e. to fixate on it, without actually perceiving it. It is also possible to stare emptily into space and think about completely different things than about the point that is fixed. Covert attention, which occurs during the recording of eye movements, could mean that the fixations are only recorded where the eye is looking, and not what the mind is actually processing. There is therefore always the possibility that fixation and attention processes are not directly coupled, which is an inherent challenge for cognitive research (Wolff, 2015). In addition, conclusions such as that certain students are often fixated on basal bottom-up processes could be traced back. For example, dynamic stimuli (such as students in the classroom) or other factors such as certain colors automatically attract attention rather than being directly linked to top-down information (cf. Itti, 2005). The conclusion for Study 6, for example, that novices are aware of the importance of students for classroom management may therefore only be based on bottom-up processes and not on their knowledge base. It would be conceivable to conduct a study comparing eye movements in teaching stimuli with novices from other domains and prospective teachers in order to obtain more precise information about them. Assuming that all novices would have similar fixations on the students, this would rather speak for bottom-up processes due to dynamic characteristics. If, on the other hand, the prospective teachers would fixate on the students more often than the other novices, this would suggest top-down participation already for novices. Altogether, triangulation is essential for a well-founded interpretation of eye movement data. Therefore, eye-tracking needs the use of several data sources to draw conclusions about the underlying cognitive processes or the cognitive model (Choi, Mosley, & Stark, 1995). Several of the studies dealt with this issue, as Studies 1 and 2 cross-validated their eye-tracking measures with an assessment of the lesson (with the CLASS-instrument, Pianta, La Paro, & Hamre, 2008). Studies 2 and 6 integrated additional information about the students in the classroom (in Study 2, with data of behavior or academic performance, in Study 6, with predefined roles of the simulated students). Verbal information from the participants were included in Study 9 (thinking aloud about the classroom scenes), Study 10 (to assess the awareness of the disturbing students), as well as in Studies 7 and 8 (timestamps; the participants needed to press a button when they noticed relevant scenes in the video).

Further analyses are also appropriate with regard to some parameters, such as scanpath analysis (Studies 3 and 5). These indicators offer a promising opportunity to gather additional information from the data, such as if and when teachers perceive situations and the order of fixed objects, which in turn could be used to draw conclusions about underlying cognitive processes (e.g. didactical strategies or aims).

5.5 Limitations of the systematic review

Publication bias is one of the major limitations of especially systematic literature reviews. (cf. Nelson, Simmons & Simonsohn, 2018; Zawacki-Richter et al., 2020). By using three different databases (ERIC, PsycINFO and the Web of Science), no restrictions in the search criteria (except for content) and a complementary search via Google Scholar, and additional referencing, we tried to keep the publication bias as low as possible. However, it cannot be excluded that there is further literature that was not found, because the search could not be all-encompassing.

Lastly, the present systematic review can give no information about the overall statistical effects due to the limited number of studies available and their heterogeneity concerning the sample, parameters and method of analysis. Similarly, due to the limited number of studies, it is difficult to make statements about the exact interpretation possibilities of the individual parameters. Although the few studies differed in some serious points, the results nevertheless indicate that professional vision, especially noticing, can be acquired using eye-tracking. A meta-analysis, if a majority of studies are available, would be appropriate in order to be able to really assess the suitability of individual parameters. In addition, the other possible influencing factors such as sample or methodology would have to be controlled.

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Appendix

Figure A: Flow diagram of the study selection process

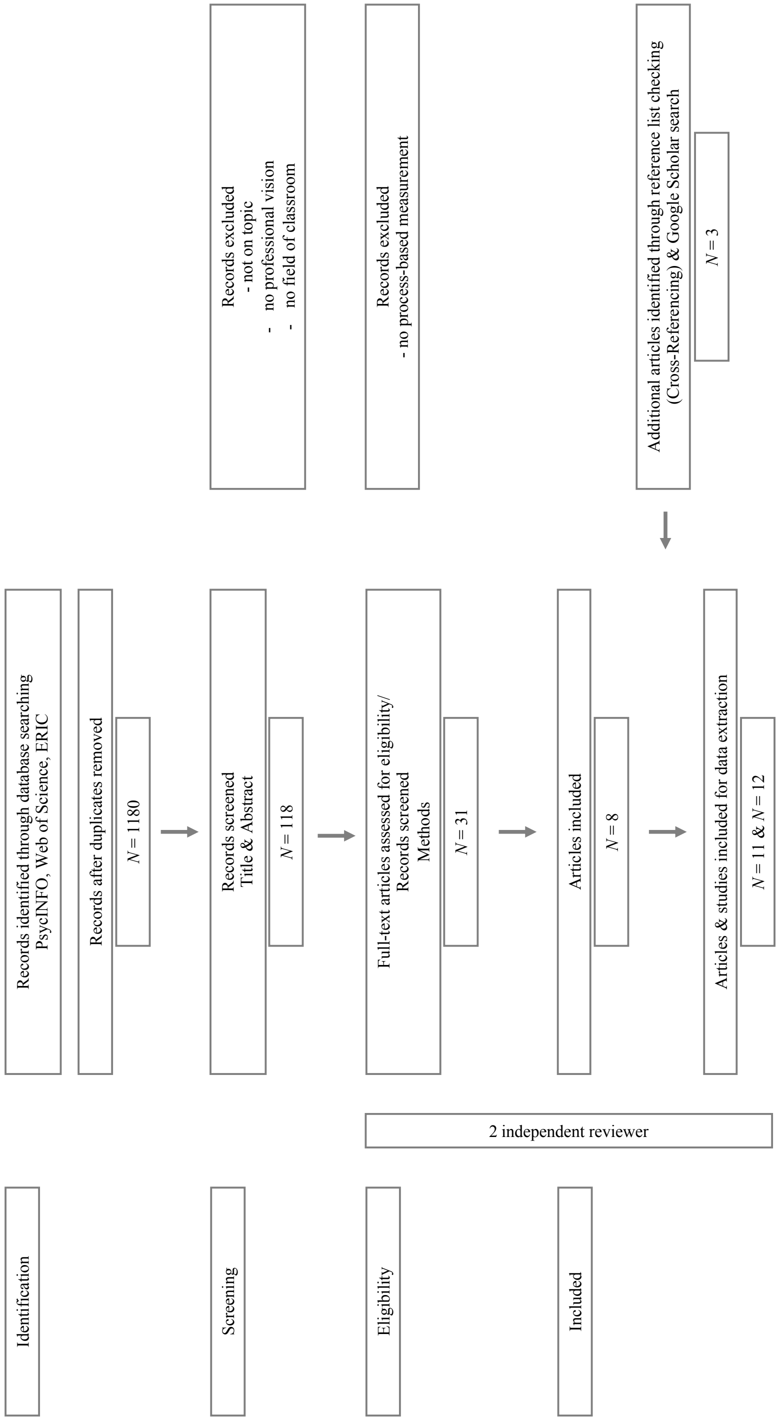

Table A: Search strings

Topic and cluster	Search terms
Process-based measurement	eyetrack* OR eye-track* OR eye track* OR tag* OR annotation* OR gaze* OR "eye tracking" OR tag* OR "video annotations" OR "mobile eye-tracking" OR "eye-tracking" or gaze*
Professional vision	"professional vision" OR "professional development" OR awareness
(Prospective) teachers	teach* OR expert* "teacher expertise" OR "teacher noticing" OR "teacher education" OR "teacher knowledge" OR "teacher attention" OR "expert-novice paradigm"
Field of classroom management	classroom* OR "classroom management" OR "classroom perception" OR "classroom simulation" OR "classroom observational assessment" OR "classroom techniques"