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Teacher Expertise and Professional Vision: Examining Knowledge-Based Reasoning of Pre-Service Teachers, In-Service Teachers, and School Principals

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Classroom professional vision is a teaching skill that refers to the ability of teachers to rapidly notice information in class and engage in knowledge-based reasoning about the noticed information. Knowledge-based reasoning includes three interrelated processes: description, explanation, and prediction. The present study aimed to examine how pre-service teachers, in-service teachers, and school principals differed in these three reasoning processes after viewing classroom photographs with varying presentation time and interactional complexity. A 3 × 2 × 4 factorial design was used. Teacher expertise (pre-service teachers vs. in-service teachers vs. school principals) was a between-group factor, presentation time (1 vs. 3 s) and complexity (teacher vs. dyad vs. small group vs. whole class) were within-group factors. Analysis of verbal reports suggested that in-service teachers and school principals used significantly more episodic knowledge, content knowledge, and pedagogical content knowledge in their reasoning than pre-service teachers did. Explanations with mathematical content knowledge were more frequent for in-service teachers, for shorter rather than longer presentation times, and for photographs showing the teacher only. Explanations with pedagogical content knowledge were more frequent for in-service teachers, for shorter rather than longer presentation times, and for photographs showing a small group. Across time and complexity, school principals verbalized less frequently what they noticed. In-service teachers and school principals verbalized significantly more self-monitoring and more predictions of teacher actions than pre-service teachers. The study findings contribute to the growing body of evidence on classroom professional vision, teacher noticing, and visual teacher expertise, and provide initial evidence on expert teachers' frequent metacognitive self-monitoring.

Keywords: knowledge-based reasoning, teacher expertise, classroom professional vision, noticing, teaching competence, self-monitoring, teacher education

INTRODUCTION

Classroom professional vision is the ability of teachers to rapidly notice information in class and engage in knowledge-based reasoning about the noticed information (Van Es and Sherin, 2008; Sherin et al., 2011; Seidel and Stürmer, 2014; Gegenfurtner, 2020). The present study examines how the latter component of professional vision—knowledge-based reasoning—differs between pre-service teachers, in-service teachers, and school principals who were tasked to view classroom situations of varying complexity and presentation time. As such, the study contributes to the growing body of evidence on classroom professional vision and teacher expertise.

Classroom Professional Vision and Teacher Expertise

Charles Goodwin developed the concept of *professional vision* in the 1990's. In his words, professional vision refers to a set of "discursive practices used by members of a profession to shape events in the domain of professional scrutiny they focus their attention upon" (Goodwin, 1994, p. 606). The notion of professional vision was later used in research on teaching and teacher education to frame how teachers perceive and observe what happens during class. For example, Keppens et al. (2019) reported that teachers' professional vision was oriented toward teacher-student interactions and differentiated instruction. Meschede et al. (2017) showed that professional vision and pedagogical content knowledge were highly interrelated. These studies frame professional vision as a teaching competence necessary for achieving high levels of teaching quality in schools. As such, professional vision is seen as a skill that grows and develops as expertise unfolds (Gegenfurtner, 2020; Lehtinen et al., 2020). Indeed, research shows that pre-service teachers' professional vision improves following practical school training (Weber et al., 2020) and video-based courses on effective teaching (Stürmer et al., 2013).

Even before Goodwin (1994) coined the term professional vision, studies examined teacher expertise in terms of their ability to rapidly process classroom information and interpret the observed information. One of these pioneering studies by Carter, Cushing, Sabers, Stein, and Berliner was published in 1988. In that study, Carter et al. (1988) explored expert-novice differences in perceiving and understanding classroom information; they used two tasks: the *Quick Look* task, in which participants viewed photographic slides for one second, and the *Look Again* task, in which participants viewed new photographs "for three seconds, and the participants were asked to write down everything they noticed. For this task each slide was shown a second and a third time, and subjects were asked to record any additional information they noticed" (Carter et al., 1988, p. 26). Their findings suggested that expert teachers had "a rich store of classroom knowledge about both students and events, and they use that knowledge to understand and explain classroom phenomena" (Carter et al., 1988, p. 31). Their conclusion has since been replicated in a number of studies and has provided further evidence for the fact that teacher expertise is associated with elaborated knowledge-based reasoning of observed classroom situations (see, e.g., recent examples of Schäfer and Seidel, 2015; Meschede et al., 2017; Wolff et al., 2017; Kim and Klassen, 2018; Yang et al., 2019).

These classroom situations can vary in interactional complexity. For example, in mathematics education, sometimes a teacher works closely with a single student, forming a student-teacher dyad. At other times, students work in small groups of four or five. And sometimes the teacher uses direct instruction to teach the whole class simultaneously. These different levels of interactional complexity—teacher, student-teacher dyad, small group, whole class—have different processing demands in working memory. Pre-service teachers in particular are likely to experience cognitive overload in highly complex scenarios given their relative lack of experience (Kim and Klassen, 2018). While it seems intuitive to assume that a higher multiplicity and complexity of situations increase processing demands, to our knowledge, interactional complexity has not yet been studied as a moderator of professional vision and knowledge-based reasoning of teachers.

Professional Vision and Knowledge-Based Reasoning of Teachers

In conceptualizing professional vision, Seidel and Stürmer (2014) proposed to differentiate noticing and reasoning as two components of teachers' professional vision. Noticing is the act of selectively attending to information in classroom situations (Van Es and Sherin, 2008; Schack et al., 2017) while reasoning is the act of interpreting noticed information based on knowledge. In their framework, Seidel and Stürmer (2014) modeled knowledge-based reasoning as a set of three interrelated processes: description, explanation, and prediction.

First, description refers to verbalizing selected information of a given classroom situation and represents the ability to say what is perceptually noticed without additional explanations. For example, teachers might verbalize that they see a small group of students engaged in a mathematical problem-solving task.

Second, explanation refers to verbalizing interpretations of the selected information and represents the meaning making of a classroom situation. Explanation processes include the organization of selected information, professional knowledge, and metacognitive self-monitoring. Particularly, selected pieces of information are organized in working memory into mental models of the perceived classroom situation. These organized mental models are further enriched and integrated with professional knowledge retrieved from long-term memory; types of professional knowledge are, to take the same example, episodic knowledge of previous teaching experiences, content knowledge of mathematics problems, and pedagogical content knowledge of math problem-solving in small student groups. Importantly, processes of organizing selected information and integrating mental models with professional knowledge are supported through self-monitoring. For example, teachers might use metacognitive strategies to monitor and self-evaluate the accuracy of their explanations.

Third, prediction refers to future-oriented consequences of the explained classroom situations. Predictions can be oriented toward consequences for student learning and subsequent actions that might unfold after the observed scene. For example, participants can predict what teachers do next, or offer alternative actions they would take to manage the observed classroom situation.

Seidel and Stürmer (2014) reported valid evidence for the three processes of description, explanation, and prediction. This three-dimensional structure of reasoning was further supported in a number of related examinations (Stürmer et al., 2013, 2016; Schäfer and Seidel, 2015). This impressive body of work tends to be based on pre-service teachers; in-service teachers or school principals were not sampled. To advance the field on teacher expertise, analyses including pre-service teachers, in-service teachers, and school principals would help to deepen our understanding of classroom professional vision and identify differences in the three reasoning processes of description, explanation, and prediction. Furthermore, a majority of studies on teacher reasoning is video-based, using recordings of several minutes or longer. Yet, if it is true that speed is a hallmark of expertise, then it would advance the field if participants viewed classroom situations for a very short time only—within the range of a few seconds—to capture expert teachers' rapid information processing (Carter et al., 1988), even when the presented classroom scenes are interactionally complex. Solid grounds for building such evidence are the two tasks *Quick Look* and *Look Again* of Carter's et al. (1988) seminal work.

Research Question and Hypotheses

The aim of this study was to explore knowledge-based reasoning as a component of classroom professional vision. Based on Seidel and Stürmer's (2014) structural model of professional vision, knowledge-based reasoning was conceptualized in three dimensions: description, explanation, and prediction. The research question was: To what extent does knowledge-based reasoning differ by expertise, presentation time, and complexity? A set of two hypotheses was formulated. First, we expected that pre-service teachers would verbalize more descriptions (Hypothesis 1a), while in-service teachers and school principals would verbalize more explanations (Hypothesis 1b) and predictions (Hypothesis 1c). Second, we assumed that knowledge-based reasoning differed by presentation time (Hypothesis 2a) and complexity (Hypothesis 2b), with more verbalizations when the classroom scenes were more complex and presented longer.

METHODS

Participants

To answer this research question, we recruited 74 people (43 female, 31 male) on three levels of expertise: 25 pre-service teachers, 24 in-service teachers, and 25 school principals. The pre-service teachers (16 female, nine male) had a mean age of 23.84 years ($SD = 1.95$), had been in teacher education for 6.64 semesters ($SD = 2.34$), and were not in service yet. They were conveniently recruited from the pool of mathematics education students in a full-time university teacher education program. The in-service teachers (16 female, eight male) were on average 48.63 years old ($SD = 8.61$) and had been in service for an average of 18.10 years ($SD = 9.61$); they were secondary school mathematics teachers and recruited through social nomination from their school's principal, teacher colleagues, or ministry officials based on their teaching excellence. The school principals (11 female, 14 male) had a mean age of 47.96 years ($SD = 8.84$) and 20.38 years ($SD = 9.08$) of teaching experience; they worked as school leaders at gymnasiums[1]. Anonymity and confidentiality were guaranteed for all responses. Participation in the study was voluntary.

Material

Participants viewed a set of photographs showing problem-solving situations in eighth grade mathematics education. The photographs were video stills created from the validated video material of Hugener et al. (2007) and showed a teacher, students, as well as instructional material like books, blackboards, and work sheets. The material included four levels of interactional complexity: (a) teacher only, (b) student-teacher dyad, (c) small group, and (d) whole class, with three photographs in each level of complexity. The photographs were hierarchically presented to participants, starting with the lowest level of interactional complexity (teacher only) and ending with the highest level (whole class). Within each level, the order of photographs was randomized. All material was presented on a 22-inch TFT monitor with a resolution of $1,680 \times 1,050$ pixels.

Presentation Time

The study included two tasks: *Quick Look* and *Look Again* (Carter et al., 1988). In Task 1 (*Quick Look*), participants viewed twelve photographs for 1 s each (three per level of interactional complexity). After each photograph, participants were asked, "What did you notice?" and could verbalize their perceptions while their statements were recorded. In Task 2 (*Look Again*), participants viewed twelve new photographs for duration of 3 s each. Participants received the same prompt as in Task 1—"What did you notice?"—and verbalized their perceptions. Subsequently, participants viewed the identical photographs a second and then a third time for 3 s each and received the same prompt, with the opportunity to "look again" and verbalize additional thoughts.

Measures

Measures in this study included participants' demographic variables and verbal reports. Demographic variables were measured with a paper-and-pencil questionnaire, with one question each to report participant age (in years) and gender. Additionally, pre-service teachers were asked in which semester they studied while in-service teachers were asked for their years of teaching experience (in years).

Verbal reports were measured with a voice recorder. Trained student assistants transcribed the voice recordings verbatim and coded the transcripts. Codes were segmented following Strijbos et al.'s (2006) unit of analysis and segmentation procedure. Interrater reliability of coding the transcripts was generally high,

[1]This group included four external evaluators who performed ministerial school inspections. Differences in demographic variables were non-significant, so we grouped the twenty-one principals and four evaluators.

with Cohen's $\kappa = 0.83$. Coding was performed with the coding scheme shown in **Table 1**. The coding scheme included seven codes covering the three reasoning dimensions of description, explanation, and prediction.

Procedure

Before starting data collections, participants signed consent forms and reported their demographic background. Participants were then comfortably seated with ∼60–80 cm monitor distance. They were informed that the study included two tasks, that they would be viewing photographs of eighth grade mathematics classes, and that photographs would switch automatically. Participants viewed one photograph as a practice trial before the data collection started, to assure they were familiar and felt comfortable with the procedure; this practice trial was not included in the analysis. At the end, participants were given opportunity to ask questions about the study's aims and background and were thanked for their participation. The data collections were performed in individual sessions and took ∼35 min per person.

RESULTS

An alpha level of 0.05 was used for the statistical tests. Three-way analyses of variance with the factors expertise, time, and complexity were performed for all verbal codes. **Table 2** presents means and standard deviations. Results are reported for the three knowledge-based reasoning categories description, explanation, and prediction (Seidel and Stürmer, 2014).

Description

Concerning the code SI (selecting information), there was a significant expertise × time interaction, $F_{(2,72)} = 3.93$, $p = 0.02$, $\eta_p^2 = 0.10$, and a significant time × complexity interaction, $F_{(3,71)} = 6.84$, $p < 0.001$, $\eta_p^2 = 0.22$. The main effect of expertise was significant, $F_{(2,72)} = 44.54$, $p < 0.001$, $\eta_p^2 = 0.55$, with school principals verbalizing fewer descriptions than pre-service and in-service teachers. The main effect of time was significant, $F_{(1,73)} = 129.92$, $p < 0.001$, $\eta_p^2 = 0.64$, with more descriptions in task 1. The main effect of complexity was significant, $F_{(3,71)} = 3.48$, $p = 0.015$, $\eta_p^2 = 0.13$, with more descriptions in the teacher and whole class conditions.

Explanation

Concerning the code OI (organizing selected information), there was a significant main effect of expertise, $F_{(2,72)} = 10.01$, $p = 0.002$, $\eta_p^2 = 0.22$, with in-service teachers and school principals organizing significantly more than pre-service teachers. The main effects of complexity, $F_{(3,71)} = 47.86$, $p < 0.001$, $\eta_p^2 = 0.67$, and time were significant, $F_{(1,73)} = 75.14$, $p < 0.001$, $\eta_p^2 = 0.51$, suggesting significantly more organizations in task 1.

Concerning the code EK (retrieving episodic knowledge), there were main effects of expertise, $F_{(2,72)} = 7.76$, $p < 0.001$, $\eta_p^2 = 0.22$, and complexity, $F_{(3,71)} = 47.86$, $p = 0.03$, $\eta_p^2 = 0.67$, indicating more verbalizations of past experiences when participants had higher levels of expertise and watched more complex photographs.

Concerning the code CK (retrieving content knowledge), there were significant expertise × complexity, $F_{(6,68)} = 2.69$, $p = 0.013$, $\eta_p^2 = 0.19$, and time × complexity interactions, $F_{(3,71)} = 14.21$, $p < 0.001$, $\eta_p^2 = 0.38$. The main effects of expertise, $F_{(2,72)} = 10.82$, $p < 0.001$, $\eta_p^2 = 0.23$, complexity, $F_{(3,71)} = 90.28$, $p < 0.001$, $\eta_p^2 = 0.79$, and time were significant, $F_{(1,73)} = 14.27$, $p < 0.001$, $\eta_p^2 = 0.16$. Explanations with mathematical content knowledge were more frequent for in-service teachers compared with pre-service teachers and school principals, for task 1 compared with task 2, and for photographs showing the teacher only compared with higher levels of interactional complexity.

Concerning the code PCK (retrieving pedagogical content knowledge), there were significant main effects of expertise, $F_{(2,72)} = 2.94$, $p = 0.05$, $\eta_p^2 = 0.08$, complexity, $F_{(3,71)} = 21.77$, $p < 0.001$, $\eta_p^2 = 0.48$, and task, $F_{(1,73)} = 63.67$, $p < 0.001$, $\eta_p^2 = 0.47$. Explanations with pedagogical content knowledge were more frequent for in-service teachers compared with pre-service teachers and school principals, for task 1 compared with task 2, and for photographs showing a small group compared with other levels of interactional complexity.

Concerning the code SM (self-monitoring), there was a significant main effect of expertise, $F_{(2,72)} = 12.41$, $p < 0.001$, $\eta_p^2 = 0.26$, suggesting that pre-service teachers verbalized significantly fewer metacognitive self-monitoring than in-service teachers and school principals did.

Prediction

Concerning the code TA (teaching actions), there was a significant main effect of expertise, $F_{(2,72)} = 10.47$, $p < 0.001$, $\eta_p^2 = 0.23$, suggesting that school principals and in-service teachers verbalized significantly more teaching actions than pre-service teachers did.

DISCUSSION

Based on Seidel and Stürmer's (2014) conceptualization of classroom professional vision and Carter's et al. (1988) *Quick Look* and *Look Again* tasks, this study aimed to explore the reasoning processes description, explanation, and prediction of pre-service teachers, in-service teachers, and school principals. The goal was to analyse how verbalisations differed by expertise, time, and complexity in order to advance our understanding of knowledge-based reasoning as a component of teachers' professional vision and expertise. In closing, we discuss the principal findings, implications for theory and practice, as well as limitations and future research directions.

Principal Findings

The major findings demonstrated, first, that in-service teachers and school principals engaged in more knowledge-driven reasoning than pre-service teachers. Particularly in-service teachers verbalized more instances in which they used episodic knowledge, content knowledge, and pedagogical content knowledge to explain the observed classroom situation (Hypothesis 1b). Both groups of experts also produced a higher number of predictions than pre-service teachers did (Hypothesis

TABLE 1 | Coding scheme.

Category	Code	Protocol segment	Keywords
Description			
Selecting information	SI	"I see a teacher and a student talking"	Teachers, students, class, classroom
Explanation			
Organizing selected information	OI	"The student doesn't seem to understand"	Student understanding, teacher engagement, classroom management
Retrieving episodic knowledge	RE	"Once I made the same experience"	Once, in my experience, happened in my lessons
Retrieving content knowledge	RC	"The circular equation is…"	Cuboid, three-dimensional fields, geometry
Retrieving pedagogical content knowledge	RP	"In math education, you secure the results by…"	Cognitive activation, group work, learning atmosphere, feedback
Self-monitoring	SM	"I'm not sure, I would like to look at the picture again"	Unsure, look again
Prediction			
Teaching actions	TA	"Now the teacher can…" / "If I was the teacher, then…"	Predictions of teacher actions

1c). These outcomes are in line with Carter's et al. (1988) original results and support their interpretation that highly developed memory structures of in-service teachers facilitated their reasoning processes—particularly in explaining classroom phenomena—relative to pre-service teachers in the very beginning of their teaching careers. As such, the study findings contribute to previous research evidence on the superiority of knowledge-based reasoning in experienced teachers compared with student teachers (Schäfer and Seidel, 2015; Meschede et al., 2017; Wolff et al., 2017; Kim and Klassen, 2018; Krepf et al., 2018; Yang et al., 2019; Gegenfurtner, 2020) and add to the broader literature on professional expertise (Damşa et al., 2017; Craig, 2019; Neumann et al., 2019; Szulewski et al., 2019b; Backfisch et al., 2020; Begrich et al., 2020; Boshuizen et al., 2020). Hypotheses 1b and 1c are thus supported.

The present study extends Carter et al.'s work because it includes a second expert group: school principals. While in-service teachers and school principals were comparable in many verbal codes, an important difference emerged for selecting information (Hypothesis 1a): school principals verbalized less frequently what they saw than in-service and pre-service teachers. This difference could be attributable to the task of many school principals to evaluate, feedback, and counsel the teaching of their teaching staff in school inspections (Tarelli et al., 2012; Lankes et al., 2013; Mägdefrau, 2019; Amador, 2020); it seems likely that their observation routines resulted in fewer verbalizations what they observed and more verbalizations how they organized their observations in mental models of the observed classroom situation.

A strong expertise difference emerged for self-monitoring strategies, with more metacognitive verbalisations of in-service teachers and school principals compared with pre-service teachers. Research in related domains indicates that self-monitoring is a characteristic of expertise, for example in sport (MacIntyre et al., 2014; McCardle et al., 2019), management (Birney et al., 2012), and medicine (White et al., 2018; Szulewski et al., 2019a). Evidence in the teaching profession is yet rare, so this finding in the present study offers first evidence that metacognitive self-evaluations are associated with teacher expertise.

The findings suggest that presentation time and complexity moderated the reasoning process. Differences were, however, not in the expected direction: while we hypothesized that longer presentation times would result in more verbalizations (Hypothesis 2a), the opposite was the case, with fewer verbal codes in the *Look Again* compared with the *Quick Look* tasks. Future research needs to replicate if people externalize more to compensate for short presentation times or if people feel verbalizations become obsolete once the same stimuli are visually processed.

Implications for Theory and Practice

Implications of the study are associated with expertise theory and teacher education. In terms of theoretical implications, evidence associated with the coding scheme reported here helps develop finer categories of the three dimensions description, explanation, and prediction (Seidel and Stürmer, 2014) based on seven codes; importantly, metacognition was added to the explanation dimension. Indeed, self-monitoring proved to be significantly different between pre-service teachers and the two expert groups, so future research can examine metacognitive dimensions in lieu of the more cognitively oriented dimensions of describing, explaining, and predicting observed classroom events. Furthermore, this study is among the first to explore the professional vision of school principals, an important but yet understudied expertise group. It is hoped that the findings presented here can inspire additional activities into theory building and empirical analyses of school leaders' professional vision.

In terms of practical implications, the findings signal that metacognitive self-evaluations are associated with expertise. Teacher education programs in universities and higher education institutes can use this finding to focus not only on developing noticing and reasoning skills, but also on developing self-monitoring skills of pre-service teachers during internships and practical school training (Mertens and Gräsel, 2018; Weber et al., 2020). Such a focus would shift the emphasis from purely training cognition to training metacognition as well (White et al., 2018; McCardle et al., 2019).

TABLE 2 | Means (and standard deviations) of verbal codes.

	Description	Explanation					Prediction
	SI	**OI**	**EK**	**CK**	**PCK**	**SM**	**TA**
Pre-service teachers							
Overall	0.93 (1.11)	1.17 (1.18)	0.00 (0.06)	0.05 (0.22)	0.22 (0.51)	0.05 (0.22)	0.01 (0.09)
Quick look							
All	1.38 (1.15)	1.41 (1.14)	0.00 (0.06)	0.07 (0.25)	0.31 (0.58)	0.05 (0.21)	0.01 (0.13)
Teacher	1.51 (1.27)	1.12 (1.03)	0.00 (0.00)	0.22 (0.42)	0.15 (0.36)	0.03 (0.16)	0.03 (0.23)
Dyad	1.15 (1.22)	1.49 (1.22)	0.01 (0.12)	0.04 (0.20)	0.28 (0.65)	0.05 (0.23)	0.00 (0.00)
Small Group	1.39 (1.06)	1.49 (1.23)	0.00 (0.00)	0.00 (0.00)	0.47 (0.68)	0.04 (0.20)	0.01 (0.12)
Whole Class	1.48 (1.03)	1.51 (1.03)	0.00 (0.00)	0.01 (0.12)	0.32 (0.55)	007 (0.25)	0.00 (0.00)
Look again							
All	0.78 (1.05)	1.09 (1.19)	0.00 (0.07)	0.04 (0.21)	0.19 (0.48)	0.04 (0.23)	0.01 (0.07)
Teacher	0.80 (1.05)	0.61 (0.83)	0.00 (0.00)	0.10 (0.33)	0.10 (0.32)	0.04 (0.23)	0.00 (0.07)
Dyad	0.79 (1.10)	1.08 (1.21)	0.01 (0.09)	0.02 (0.13)	0.14 (0.44)	0.05 (0.23)	0.00 (0.07)
Small Group	0.78 (1.06)	1.40 (1.18)	0.00 (0.07)	0.04 (0.19)	0.31 (0.58)	0.03 (0.17)	0.00 (0.00)
Whole Class	0.77 (1.24)	1.27 (1.31)	0.00 (0.07)	0.00 (0.00)	0.21 (0.53)	0.05 (0.27)	0.01 (0.12)
In-service teachers							
Overall	1.00 (1.26)	1.37 (1.44)	0.01 (0.12)	0.09 (0.33)	0.25 (0.60)	0.12 (0.36)	0.02 (0.14)
Quick look							
All	1.41 (1.34)	1.62 (1.41)	0.03 (0.16)	0.12 (0.37)	0.39 (0.87)	0.10 (0.35)	0.04 (0.21)
Teacher	1.50 (1.24)	1.39 (1.24)	0.00 (0.00)	0.33 (0.56)	0.38 (1.29)	0.13 (0.45)	0.04 (0.21)
Dyad	1.01 (1.13)	1.57 (1.16)	0.04 (0.21)	0.13 (0.38)	0.35 (0.66)	0.06 (0.29)	0.04 (0.21)
Small Group	1.51 (1.47)	1.68 (1.64)	0.03 (0.17)	0.00 (0.00)	0.51 (0.83)	0.06 (0.24)	0.04 (0.27)
Whole Class	1.64 (1.41)	1.86 (1.55)	0.03 (0.17)	0.01 (0.12)	0.33 (0.53)	0.16 (0.37)	0.01 (0.12)
Look again							
All	0.87 (1.20)	1.29 (1.44)	0.01 (0.10)	0.08 (0.31)	0.21 (0.48)	0.13 (0.36)	0.01 (0.12)
Teacher	0.95 (1.20)	0.65 (0.84)	0.00 (0.07)	0.22 (0.50)	0.11 (0.34)	0.19 (0.43)	0.02 (0.14)
Dyad	0.84 (1.18)	1.52 (1.61)	0.01 (0.12)	0.05 (0.22)	0.20 (0.49)	0.13 (0.39)	0.02 (0.14)
Small Group	0.94 (1.28)	1.46 (1.58)	0.00 (0.07)	0.04 (0.22)	0.35 (0.57)	0.09 (0.32)	0.01 (0.12)
Whole Class	0.75 (1.13)	1.53 (1.41)	0.02 (0.14)	0.02 (0.17)	0.19 (0.46)	0.10 (0.31)	0.00 (0.07)
School principals							
Overall	0.61 (0.97)	1.30 (1.32)	0.03 (0.16)	0.04 (0.21)	0.25 (0.56)	0.08 (0.29)	0.04 (0.21)
Quick look							
All	0.85 (0.13)	1.57 (1.25)	0.03 (0.16)	0.07 (0.26)	0.41 (0.70)	0.06 (0.26)	0.04 (0.20)
Teacher	0.76 (1.04)	1.09 (0.99)	0.00 (0.00)	0.27 (0.45)	0.24 (0.54)	0.05 (0.23)	0.03 (0.16)
Dyad	0.73 (1.28)	1.85 (1.26)	0.01 (0.12)	0.03 (0.16)	0.28 (0.53)	0.08 (0.32)	0.04 (0.20)
Small Group	0.89 (1.05)	1.67 (1.31)	0.04 (0.20)	0.00 (0.00)	0.63 (0.85)	0.03 (0.16)	0.04 (0.20)
Whole Class	1.01 (1.16)	1.67 (1.31)	0.05 (0.23)	0.00 (0.00)	0.51 (0.74)	0.07 (0.30)	0.05 (0.23)
Look again							
All	0.53 (0.90)	1.21 (1.32)	0.02 (0.16)	0.03 (0.19)	0.20 (0.49)	0.09 (0.30)	0.04 (0.21)
Teacher	0.61 (0.80)	0.87 (1.09)	0.02 (0.15)	0.09 (0.34)	0.17 (0.48)	0.11 (0.32)	0.05 (0.22)
Dyad	0.59 (1.03)	1.47 (0.56)	0.01 (0.09)	0.02 (0.13)	0.17 (0.44)	0.08 (0.28)	0.04 (0.21)
Small Group	0.47 (0.90)	1.20 (1.21)	0.03 (0.16)	0.02 (0.13)	0.28 (0.60)	0.10 (0.34)	0.03 (0.19)
Whole Class	0.45 (0.84)	1.26 (1.32)	0.04 (0.20)	0.00 (0.00)	0.16 (0.41)	0.06 (0.24)	0.05 (0.24)

SI, selecting information; OI, organizing selected information; EK, retrieving episodic knowledge; CK, retrieving content knowledge; PCK, retrieving pedagogical content knowledge; SM, self-monitoring; TA, teacher actions.

Limitations and Future Research Directions

Limitations of the study are associated with the material and verbal report data. First, the material—photographs of classroom situations—copied the material used in Carter's et al. (1988) seminal work in an attempt of replicating their findings. Any differences in knowledge-based reasoning in the present study are contingent on the static, two-dimensional material used and should only cautiously be generalized to other material. Future studies can aim to test differences for dynamic and/or three-dimensional representations of classroom situations such as video (Stürmer et al., 2016; Barth et al., 2019; Gegenfurtner et al., 2019; Walsh et al., 2020) as watching video tapes of real-classroom teaching will be more authentic. Second, this study used verbal data as indicators of the reasoning processes description, explanation, and prediction (Carter et al., 1988; Seidel and Stürmer, 2014; Schäfer and Seidel, 2015)—although it is understood that teachers' ability to verbally express their views is not the same as the ability to apply the knowledge appropriately in the classroom context. Corresponding with the inference metaphor in visual expertise research (Gegenfurtner and Van Merriënboer, 2017), our decision to use verbal reports was grounded on our interest in knowledge-based reasoning as one of the two components of classroom professional vision. The related component, noticing (Sherin et al., 2011; Schack et al., 2017), could be examined in follow-up studies with additional data sources such as eye tracking (Szulewski et al., 2019b; Gegenfurtner et al., 2020) to complement and triangulate the analyses of verbal data.

CONCLUSION

In conclusion, this study explored knowledge-based reasoning of pre-service teachers, in-service teachers, and school principals based on their rapid processing of briefly presented classroom scenes situated in eighth grade mathematics education. The significance of the study is associated with (a) identifying metacognitive self-monitoring as an important part of classroom professional vision and (b) comparing the understudied group of school leaders and principals with the frequently studied groups of pre-service and in-service teachers. The study findings contribute to the growing body of evidence on classroom professional vision, teacher noticing, and visual teacher expertise, and provide initial evidence on expert teachers' self-monitoring strategies. Future research is encouraged to extend these first steps reported here to the examination of cognitive and metacognitive processes involved when teachers notice and interpret classroom information.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AG designed the study and drafted the manuscript. AG und MS collected and analyzed the data. AG, DL, EL, and HG edited the manuscript.

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