A Situated Approach to Assess Teachers' Professional Competencies Using Classroom Videos

Jessica Hoth, Gabriele Kaiser, Martina Döhrmann, Johannes König and Sigrid Blömeke

Abstract Teaching practice and its representation by videos are a central part of many empirical studies concerning the field of teaching and learning. In order to analyze how videos can help to investigate aspects of teachers' expertise, the data from 131 primary mathematics teachers who participated in the TEDS-Follow-Up study were evaluated. The teachers answered questions referring to scripted video-clips describing classroom situations. The questions were qualitatively analyzed covering the spectrum of aspects mentioned by the teachers and its relation to aspects of teachers' expertise. The analyses showed that teachers notice and mention a great number of aspects that were either directly observable in the video-clip shown, or could be identified using the given information. In addition, it is pointed out that teachers with high professional knowledge notice possible reasons for a student's error more accurately, while teachers with low professional knowledge focus on aspects that are not directly connected to the student's learning.

Keywords Teacher competence · Video based assessment · Noticing Teacher knowledge

J. Hoth (✉)
Leibniz Institute for Science and Mathematics Education,
Olshausenstrasse 62, 24118 Kiel, Germany
e-mail: hoth@ipn.uni-kiel.de

M. Döhrmann
Universität Vechta, Vechta, Germany

G. Kaiser
Universität Hamburg, Hamburg, Germany

G. Kaiser
Australian Catholic University, Brisbane, Australia

J. König
Universität zu Köln, Cologne, Germany

S. Blömeke
Centre for Educational Measurement (CEMO), University of Oslo, Oslo, Norway

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Introduction

Research about teachers' expertise and teachers' competencies used a variety of approaches to gather information about the multifaceted abilities and skills that teachers require for their teaching profession. In addition to large-scale assessments that tested teachers' knowledge and beliefs by paper-and-pencil tests (e.g., Cognitively Activating Instruction and Development of Students' Mathematical Literacy (COACTIV), Kunter et al. 2011; Teacher Education and Development Study in Mathematics (TEDS-M), Blömeke et al. 2014; and Mathematics Teaching in the 21st century (MT21), Schmidt et al. 2011), research approaches used representations close to real classroom practice in order to assess teachers' professional competences using videos (e.g., Kersting 2008; Kersting et al. 2010, 2012; Star et al. 2011; Kaiser et al. 2015), text-vignettes (e.g., Dreher and Kuntze 2015) or comic scenes (e.g., Herbst et al. 2015). In connection with these approaches, the theoretical bases of these studies often also included more situation-specific facets of teachers' professional competencies. In order to analyze how video as a tool for representing teaching practice can help to investigate aspects of teachers' expertise, this paper presents a qualitative approach to analyze teachers' noticing of a video episode and links the results to their professional knowledge. In the following, the theoretical basis concerning teachers' expertise and teachers' professional competencies will be described. Subsequently, the methodological approach of a qualitative analysis of one selected question of the TEDS-FU video instrument will be presented as well as the results of this analysis.

Theoretical Background

Teachers' Expertise and Teacher Noticing

In order to identify characteristics of expert teachers, research in the field of teachers' expertise usually contrasted experts and novice teachers (Berliner 2001). In this regard, expert and novice teachers differed with regard to their situation-specific skills that become relevant in the course of teaching. The three situation-specific facets—the perception, interpretation and decision-making during class—were prominent facets concerning the concept of teachers' noticing (Sherin et al. 2011a; Jacobs et al. 2010) and also were central components of teachers' professional competencies as they were conceptualized and assessed in some studies as the TEDS-Follow-Up study (see Section "The TEDS-Follow-Up Study", Kaiser et al. 2015).

Research showed that expert and novice teachers' *perception* differ with regard to identifying relevant aspects for children's learning. Expert teachers distinguish important and less important information while novice teachers more often perceive surface characteristics (Berliner 2001). In addition, novice teachers may more often focus on the teacher and aspects of classroom management than on the subject and the classroom discourse (Star and Strickland 2008). "When issues of content were noticed, preservice teachers tended to comment only about whether the content was presented accurately and clearly and/or to provide a chronological description of what the teacher wrote on the board during the lesson" (ibid., p. 122).

These kinds of differences also became obvious when comparing expert and novice teachers' *interpretation* of classroom situations. In this regard, Sherin et al. (2011b, p. 5) pointed out that (teachers') perception and interpretation seem to be more "interrelated and cyclical". While novice teachers rather use descriptions of what happened in class, expert teachers interpret the situation deeply and precisely (Sabers et al. 1991; Carter et al. 1988). Problems in student learning processes, which are based on complex teaching situations, may be identified faster by expert teachers while novices rather identify the error itself and, again, describe the error but do not interpret it (Chi et al. 1981).

As another difference between expert and novice teachers could be identified that "as a group, experts are much more interested in analyzing why things are happening instead of critically commenting on the fact that events have happened" (Sabers et al. 1991, p. 81). In her learning to notice framework, Van Es (2011) described different phases of teacher noticing development. Here, teacher noticing evolved with regard to what is noticed and how teachers notice. While teachers with baseline noticing may more often attend to the teacher and his or her pedagogy as well as students' behavior, teachers' noticing shifts in the subsequent stages to students' learning and the relationship between students' mathematical thinking and teaching strategies (ibid.). With regard to how teachers notice, baseline noticing is characterized by mentioning general aspects of what occurred as well as descriptive and evaluative comments. Then again, extended noticing, as the most advanced stage of noticing, includes identifying noteworthy events and providing interpretative comments that refer to specific events and interactions as evidence for what was noticed (ibid.).

In addition, expert and novice teachers seemed also to differ with regard to their *decision-making*. As Jacobs et al. (2010) analyzed—in addition to teachers' attending to and interpreting children's strategies—teachers decide on how to respond on the basis of children's understanding. The authors pointed out that the development of this specific facet can be characterized by various aspects such as "a shift from general comments about teaching and learning to comments specifically addressing the children's understandings; a shift from overgeneralizing children's understandings to carefully linking interpretations to specific details of the situation" (ibid., p. 196).

Teachers' Professional Knowledge and Its Connection to Teachers' Noticing

The differences between expert and novice teachers' perception, interpretation and decision-making processes—as described in the previous section—may have resulted from their different knowledge bases (Livingston and Borko 1989). Teachers' perceptions and interpretations were both assumed to be knowledge-based because teachers' knowledge guides their perceptions and provides the basis for their interpretations of the perceived instances (e.g., Schäfer and Seidel 2015). Following the question of how teachers' noticing is linked to their professional knowledge, the definition of teacher noticing by Van Es and Sherin (2002, p. 573; Sherin 2010b) proposed an interrelation between perception, interpretation and knowledge. "We propose three key aspects of noticing:

(1) Identifying what is important or noteworthy about a classroom situation
(2) Making connections between the specifics of classroom interactions and the broader principles of teaching and learning they represent and
(3) Using what one knows about the context to reason about classroom interactions"

As Van Es and Sherin pointed out, teachers need to perceive important classroom situations and interpret them with regard to broader principles of teaching and learning using their professional knowledge. According to Shulman (1986, 1987), the main facets of teachers' professional knowledge are (1) content knowledge (in the case of mathematics teachers, this would be the mathematics content knowledge, short: MCK), their pedagogical content knowledge ([M]PCK) and their general pedagogical knowledge (GPK). "Thus, teachers must use their knowledge of the subject matter, knowledge of how students think of the subject matter, as well as knowledge of their local context to reason about events as they unfold" (Van Es and Sherin 2002, p. 574f.).

Linking teachers knowledge to their actual performance in the classroom, Blömeke et al. (2015, see Fig. 1) proposed a model of competence as a continuum, and integrated the situation-specific skills perception, interpretation and decision-making into their model of competence as a mediator between disposition and performance. Therefore, knowledge was hypothesized underlying performance but the relation may be mediated by the situation-specific skills, "cobbled together in response to task demands, somewhat differently for each person" (ibid., p. 6).

Referring to the comparison of novice and expert teachers, it was assumed that expert teachers use their knowledge more flexibly to interpret classroom incidences while this is more problematic for novice teachers (Berliner 2001). Kersting (2008) and Kersting et al. (2010, 2012) found that teachers' mathematical content knowledge for teaching positively related to their ability to interpret classroom videos, concluding that "teachers used their pedagogical and mathematical content knowledge for teaching when analyzing classroom situations" (Kersting 2008, p. 14). Accordingly, König et al. (2014) found that teachers' skill to interpret

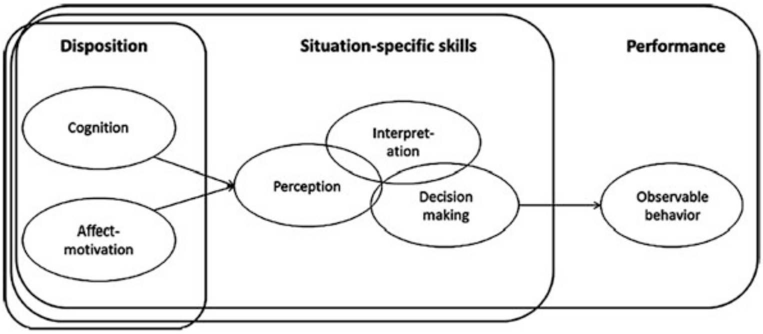

Fig. 1 Modeling competence as a continuum. Reproduced with permission from Blömeke et al. (2015), © 2015 Hogrefe Publishing

classroom incidents significantly correlates with their GPK while this connection was not found for teachers' skill to perceive specific classroom events and their GPK. With regard to comparing a video-based assessment of teachers' classroom management expertise and teachers' general pedagogical knowledge assessed by a paper-and-pencil test, König and Kramer (2016, p. 148) found that "teachers' general pedagogical knowledge and classroom management expertise are two different constructs, although they are substantially and positively inter-correlated."

However, Blomberg et al. (2011) proposed—based on their findings—that professional vision is a generic ability but not necessarily subject-related, while Dreher and Kuntze (2015, p. 110) found that "there is not a simple relationship between successful theme-specific noticing and a single component of professional knowledge. Instead, drawing on a variety of different components of professional knowledge and views can result in successful theme-specific noticing".

In this regard, Schäfer and Seidel (2015) pointed out that there is still only little research about the connection between teacher noticing and different knowledge facets. This was one of the main starting points for the following analyses that focused on mathematics teachers' noticing and its connection to their knowledge base.

Research Question

Many of the empirical studies presented in the previous section used video as a tool for representing practice to analyze teachers' expertise and teachers' noticing (cf. Schäfer and Seidel 2015; Kersting 2008; Kersting et al. 2010, 2012; Blomberg et al. 2011; Van Es and Sherin 2002). These videos had different functions in accordance with each of the respective study's research aim. For example, Van Es and Sherin (2002) used videos in teacher training (so-called video clubs) to discuss and reflect the teachers' practices with the group of participating teachers while Kersting (2008) used video to measure the quality of teachers' classroom analysis.

Following the aim to identify aspects that characterize how expert teachers notice classroom processes, the present study was based on data collected with a video test instrument and aimed at studying the following research question:

How can video, as a tool for representing teaching practice, support the investigation of aspects of teacher expertise, such as noticing (in this study the subdimensions of perception and interpretation)?

To answer this question, data collected with the video instrument of the TEDS-Follow-Up study was used, which will be described in the following section. Primary mathematics teachers' responses to a video sequence will be the focus of the following analyses and will be complemented by information about teachers' knowledge from another test part of the TEDS-Follow-Up study. The following section presents the methodological approach and describes the TEDS-Follow-Up study and its test instruments.

Methodological Approach

In order to utilize the potential that video offers to investigate aspects of teacher expertise, a qualitative approach was chosen using the data from the video-based test of the TEDS-Follow-Up study.

The TEDS-Follow-Up Study

TEDS-Follow-Up was the longitudinal Follow-Up to the international Teacher Education and Development Study in Mathematics (TEDS-M; e.g., Blömeke et al. 2014). TEDS-M was conducted under the auspices of the IEA (International Association for the Evaluation of Educational Achievement), and assessed the professional competence of future mathematics teachers at the end of their education in 16 participating countries. In Germany, about 2000 preservice teachers participated in the study in 2008. A subset of these teachers was reassessed in 2012 in the TEDS-Follow-Up study. In addition to 171 secondary school teachers, 131 primary school teachers who had about 4 years of work experience took part in the study which was realized as an online assessment. Following the model of competence as a continuum (see Fig. 1) and widening the theoretical framework, the TEDS-Follow-Up study closely referred to work in the field of teachers' expertise (Li and Kaiser 2011) and the concept of teacher noticing (Sherin et al. 2011a) and also included situation-specific skills as one main facet of teachers' competencies. More precisely, three situation-specific skills are considered:

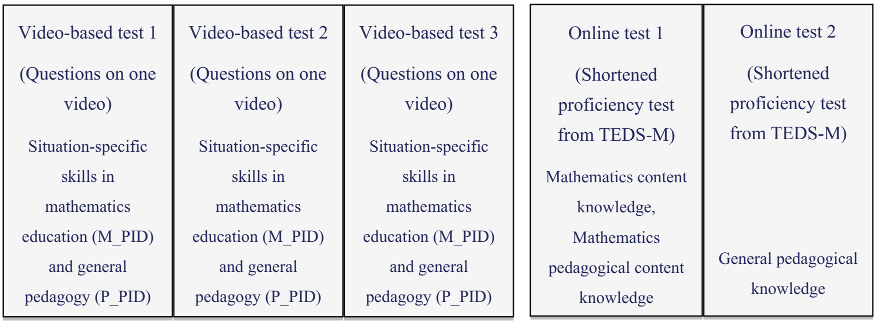

Fig. 2 Shortened design of the TEDS-follow-up study

"(a) Perceiving particular events in an instructional setting,
(b) Interpreting the perceived activities in the classroom
(c) Decision making, either as anticipating a response to students' activities or as proposing alternative instructional strategies" (Kaiser et al. 2015, p. 373).[1]

The video test instrument of the TEDS-Follow-Up study consisted of three scripted video clips with corresponding questions. In order to identify expert teachers in the sample of TEDS-Follow-Up, the knowledge scores that resulted from the online tests 1 and 2 were used to provide additional information. As discussed in Section "Teachers' Professional Knowledge and Its Connection to Teachers' Noticing", teachers' noticing may be closely connected to their expertise. Figure 2 shows a short version of the design of the TEDS-Follow-Up study containing only the parts relevant for this paper.

The video-based tests were developed for the TEDS-Follow-Up study to assess the situation-specific skills perception, interpretation and decision-making. In the video-based tests, the study participants watched three short video clips (three to five minutes) showing excerpts of mathematics classes, and were asked to answer corresponding questions afterwards. The questions were presented in closed and open formats, and referred to didactical and pedagogical aspects of the teaching episode. The videos itself were scripted classroom scenes. Each of the videos had a different mathematical topic and showed classes in different instructional phases. Concerning the videos of the primary school study, all of the three video clips presented third-grade mathematics classes. One video dealt with geometry as mathematical content, while the instructional phases in this video were the introduction of the mathematical content by the teacher as well as part of the working phase of the children. Another video showed a mathematics class searching and discussing patterns and structures in Pascal's triangle. This video started during the

[1]For a detailed description of the theoretical base and conceptualizations in the TEDS-M study, see e.g., Blömeke et al. (2014); for the TEDS-Follow-Up study e.g., Hoth et al. (2016a), Kaiser et al. (2015).

working phase and included the beginning of the final phase of the lesson where the students presented their results in a whole class discussion. The third video dealt with third-grade learners working on a real-life mathematics task. The video showed the introductory phase of the lesson as well as the accompanying group work of the students subsequent to the introductory phase.

The participating teachers were provided with background information about the mathematical content of the lesson, additional information about the class and their learning conditions as well as information about what happened in former lessons. The teachers could always re-access this information when they answered the test questions subsequent to watching the video. In order to be as close to real teaching situations as possible, the teachers were only able to watch the videos once without the option to pause, rewind or fast-forward.

Data Sampling and Data Analysis

In order to illustrate how representations of classroom practice can help to investigate aspects of teacher expertise, we selected one question of the video vignette Geometry that required teachers to notice crucial aspects with regard to children's learning in the teaching episode presented in the video. More precisely, the question focuses on those aspects of the teaching sequence that basically led to a student's errors (as described below). Therefore, all information which is given within the complex and multifaceted teaching sequence became relevant and had to be interpreted with regard to the student's understanding as shown in the video. In the following, the video vignette Geometry is described in more detail as well as the selected question.

The video shows the beginning of a geometry lesson about Pentominoes[2] in a third-grade mathematics classroom. The students and the teacher sit in a circle of chairs while the teacher introduces these special geometric figures. She explains to the students how Pentominoes are built, presents their names and also mentions the concept of congruence to the children. Thereby, she shows one Pentomino example to the children (all squares are arranged in one row; see Fig. 3) by placing five squares in the middle of the circle. She also provides a poster that lists the building criteria of Pentominoes and shows some examples (see Fig. 4); she does not give an example for congruent Pentominoes but puts up a poster that verbally covers all aspects of congruence on an abstract level. The teacher then presents the task to the children who are asked to find all existing Pentominoes and justify the number of varying figures. As assisting materials, the teacher provides little squares that each student can use individually to build their Pentominoes. After building them, the

[2]Pentominoes are plane geometric figures that consist of five squares. Each of those squares must be connected to at least one other square with one side. Figures with four squares are called Tetrominos etc. For more information about Pentominoes see Golomb (1994).

Fig. 3 Poster

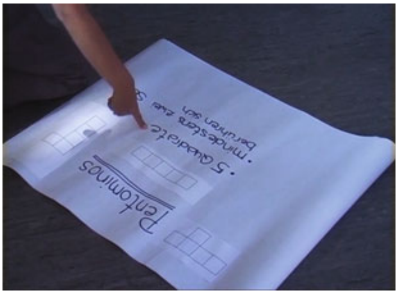

Fig. 4 Teacher example

students are also asked to draw a representation of the Pentomino into their notebooks. Finally, the children get the chance to ask questions about the content presented as well as the given task.

In the following, the video shows one girl who presents her solution to the teacher. She explains that there must be 10 Pentominoes because she has 10 options to place the 5th square (see Fig. 5). The girl also provides an idea to prove her statement. However, she also makes two mistakes in her solution process. First, she finds Pentominoes only on the basis of one specific Tetromino and, second, she does not consider congruency.

The question that was selected for the analyses in this paper draws on these mistakes and asks the teachers to analyze the teaching sequence that they saw in the video-vignette with regard to the student's errors. The teachers were asked to identify three instances in the course of the teaching process shown that may have caused the student's errors (the errors itself were named in the question: not

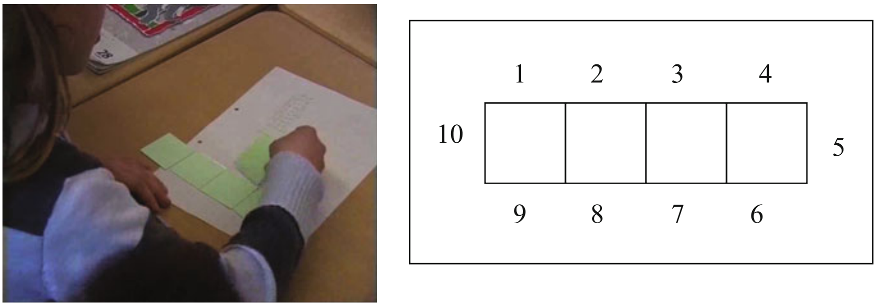

Fig. 5 Student's solution in the video-vignette "Geometry"

considering congruency and identifying Pentominoes only on the basis of one specific Tetromino). The teachers were given three open response fields.

This specific question was chosen for the following analyses because these aspects are typical for expert teachers' perception and interpretation and can be revealed through this complex question that requires the teachers to evaluate all the information they gathered in the course of watching the video. In the TEDS-Follow-Up study, teachers' answers were coded based on an extensive coding manual, which was based on in vivo-codes developed out of the test persons' answers and extensive expert ratings. For each question, 20% of the data was coded by two trained coders individually—inter-rater reliability resulting to $\kappa \approx 0.74$. In order to evaluate content-validity, several rounds of expert ratings were realized. Here, experts commented on the validity of the proposed questions (for details on the approach for analyzing of the rating-scale items see Hoth et al. 2016b).

Referring to the selected question, answers were coded as 'correct' if they presented instances that actually happened in the video. In addition, they had to refer to the student's errors and had to either explain her disregarding congruency or identifying Pentominoes only on the basis of one Tetromino. These requirements applied to five instances: (1) The teacher directly started with Pentominos, excluding preceding figures such as Tetrominoes, Triominoes etc., (2) the teacher presents one Pentomino example that also consists of that specific Tetromino, (3) the Pentomino examples on the poster were all build on the basis of that Tetromino, (4) the student did not understand the concept of congruency and (5) the didactic material which the teacher offered to find Pentominoes did not allow the students to flip and rotate their figures.

The data for the analyses were the answers of the 131 primary mathematics teachers who participated in the TEDS-Follow-Up study. As evaluation method, qualitative text analysis (cf. Mayring 2015; Kuckartz 2014) was used. Here, reducing evaluation procedures (Mayring 2015) were used to analyze the facets of the teachers' answers to the selected question. "The object of the analysis [using reducing processes] is to reduce the material such that the essential contents remain, in order to create through abstraction a comprehensive overview of the base material which is nevertheless still an image of it" (ibid., p. 373). Thus, the summarizing categories represent every aspect that the teachers mentioned with regard to the selected question and built the basis for analyzing aspects of teachers' expertise. Each category could be classified as more or less significant for explaining the student's errors and, therefore, provided information about the teachers' expertise. In this context, meaningful was related to the preciseness of the teachers' interpretations of the classroom incidents with regard to the student's errors. In addition, frequency analyses (cf. ibid.) gave insight into the distribution and emphasis of teachers' answers. The results of this inductive coding process as well as example of answers for each of the resulting categories are presented in Table 1.

The qualitative results were then related to the scores from the standardized MCK, MPCK and GPK assessments. As in the TEDS-M study, the international

Table 1 Category results of the inductive coding, teachers' example answers and frequency analysis

Category name and description	Example of an Answer[a]	Number of occurrences
Incomprehension of congruence: The student's mistake is based on her incomprehension of the concept of congruence	"The children did not understand the concept of congruency." (Teacher1164)	48
Ensuring students' comprehension: The teacher in the video did not ensure that the students understood the subject matter/the work assignment and so on	"The teacher did not check whether the children actually understood everything." (Teacher1050)	22
The teacher's example in the introduction: The student's mistake can be ascribed to the teacher presenting only one example of a Pentomino which was based on only one Tetromino in the introductory phase of the lesson	"The teacher placed that example which is based on that specific Tetromino in front of the children." (Teacher1090)	48
Missing student activities: Since the students did not have the opportunity to find and explore the Pentominoes/ their structure/congruent figures, they did not develop understanding	"The children should have worked practically on congruency." (Teacher1668)	20
More than five squares as working material: The student's mistakes may have happened due to the fact that the students had more than five squares available to work with during the working phase of the lesson	"She has more than five squares to work with." (Teacher1061)	4
The abstractness of teacher's description: The children did not understand the lesson's subject matter because the teacher's explanations were too abstract, involved too many technical terms and/or mathematical inaccurate facts	The teacher's explanation was too specialized. The students did not understand." (Teacher1294)	49
Missing motivation: The mistakes can be ascribed to missing motivation on the side of the student or the teacher failure to motivate her students	"Missing motivation" (Teacher1063)	3
Missing clarification of preceding figures: The student did not consider other Pentominoes because the teacher and her instruction did not consider the preceding figures such as Dominoes, Trominoes and Tetrominoes	"It would be possible to begin by searching all the Tetrominos (in the sitting circle)." (Teacher987)	10

(continued)

Table 1 (continued)

Category name and description	Example of an Answer[a]	Number of occurrences
Missing visual example and/or counterexample: The teacher failed to present a visual example and/or counterexample to the students that may have strengthened their understanding	"The teacher did not show an example of congruent Pentominoes." (Teacher 1217)	38
Pentomino examples on the poster: The poster that the teacher presents to the students about the building structure of Pentominoes also only shows Pentominoes that are based on the one Tetromino with all squares in one row	"The examples on the poster also show two Pentominoes made of that Tetromino." (Teacher1729)	11
Missing response to students' questions: The teacher did not respond (appropriately) to students' questions which may have negative influence on their understanding. In addition, she did not provide appropriate support such as strategic advice	"The teacher did not react on questions and suggestions of students in the beginning of the lesson." (Teacher1132)	16
Manageability of didactic material: The material that the teacher offers the students to work with does not enable the students to flip and rotate their found Pentominoes. Therefore, Karola is not able to consider congruency	"How is the girl supposed to test congruency if the Pentominoes that she finds only consist of individual components? This offers few opportunities to try out." (Teacher1278)	6
Color highlighting the Pentomino examples: The Pentominoes that the teacher provided on her poster are not optimally color highlighted	"All squares have the same color." (Teacher1665) "The alternatives on the poster are not colored clearly enough." (Teacher1209)	4
At least two sides are touching: The teacher explained the building structure of Pentominoes in that each of the five squares is touching at least one side of another square. However, the children did not understand the meaning of this statement	"Two sides of the squares have to be touching." (Teacher1691)	14
Pentominoes consist of five squares: The children did not know that the Pentominoes consist of five squares	"In Karola's solution, there are five squares in a row. She keeps positioning the sixth square to present her solution. She did not understand that a Pentomino consists of only five squares." (Teacher 1671)	4
Pentominoes' name: The children did not understand the term Pentomino as the name for the figures	"Karola does not know what Pentominos are and how they are build." (Teacher 1517)	3

(continued)

Table 1 (continued)

Category name and description	Example of an Answer[a]	Number of occurrences
Lack of student-to-student interaction: The mistakes may have occurred due to the lack of student-to-student interaction	"There was no group work or a possibility for the students to communicate with each other." (Teacher1433)	5
Answer does not refer to the question: This category subsumes all teachers' answers that do not correctly refer to the given question	"She uses the wrong equation." (Teacher979)	15

[a]A teacher's answer can include more than one aspect

average for these scores was set to 500 with a standard deviation of 100.[3] The subsample of German primary teachers who participated in the Follow-Up study had an average of 531 in their MCK and MPCK and an average of 644 in their GPK. More precisely, for each of the qualitatively found categories, the mean value was determined of those teachers' knowledge scores who named that category. The mean differences were then analyzed using *t*-tests in order to verify significant differences.

Results

In the selected task, 17 categories were constructed inductively. This high amount of categories already shows the complexity and variance of teachers' answers (see Table 1). In the following, the different categories are described and elaborated on with sample answers of the participating teachers. The third column reports the number of occurrences of each respective category within the teachers' answers. Since the teachers were asked to name three aspects[4] that may have caused the student's mistakes, teachers predominately named more than one aspect [min = 0; max = 6]. Therefore, one teacher may be assigned to more than one category and the number of occurrences does not equal the number of teachers who participated in the study. Furthermore, the answer a teacher provided in one open-response field could include more than one aspect. This evaluation procedure along categories with variable teacher groups seemed to be adequate for the evaluation of the richness of the categories identified and named by the teachers. For this qualitative coding 50% of the data was coded by two researchers independently, the interrater-reliability was satisfactory with $\kappa = 0.808$.

[3]For further details about the instruments and the scaling of the TEDS-M study see Tatto et al. (2012).

[4]There were three open response fields in the web-based test.

This analysis shows that the same video sequence and this one specific question provide the basis for different and multifaceted teacher answers. Obviously, teachers perceive different aspects in the same situation and with the same question as the starting point for their analyses, and their answers differ in regard to the aspects perceived. Some of the categories refer more closely to the student's errors and a possible explanation for the errors while others do not.

In order to understand the complexity of these categories as well as the approach that teachers used to perceive and interpret the information in the video, the categories are analyzed with regard to their appearance in the video in the following analysis. Some of the aspects mentioned by the teachers are directly observable in the video (have observable evidence in the video) while others are results of interpreting processes. This analysis, therefore, closely refers to the idea of evidence-based analysis (Van Es and Sherin 2002). For example, the category "Pentomino examples on the poster" directly refers to visual objects within the video—namely the Pentominoes which the teacher placed on her poster. However, in the video the teacher does not address these figures directly, they only appear on the poster but are not addressed by any actor in the video. Therefore, teachers who perceive these figures in the video have a rather holistic view on the teaching situation (meaning that they notice relevant aspects for student learning even if their attention is not directly alerted to it). Other categories such as "Manageability of didactic material" are an interpretative result of what was visually presented in the video but are not directly observable. In the video, one girl is shown presenting her solution to the teacher. She uses the material that the teacher offers to demonstrate her solution approach. However, she does not try to turn and rotate the Pentominoes which she already found and, therefore, the teachers whose answers belong to this category interpret the manageability of the material without seeing the student actually struggling to flip and rotate the figures.

Here, we can distinguish between categories that are perceived based on directly observable aspects in the teaching sequence and categories that result from interpreting processes. Then again, we can distinguish whether the aspects that are directly observable in the teaching scene are part of the action and, therefore, teachers' attention is directly drawn on them, or whether the aspects are observable in the background. As suggested by expertise research, novice teachers more often perceive surface characteristics in a teaching sequence while expert teachers distinguish important and less important information and interpret the situation deeply and profoundly (cf. Berliner 2001). In this regard, novice teachers may name categories that are directly observable and part of the main action while expert teachers more often name categories that result from interpreting processes.

In addition, the categories presented above can be classified with regard to their chosen perspective. While some teachers name more mathematical didactics aspects (such as the didactical material in the category "Manageability of didactical material" or the building of instruction of Pentominoes in the category "At least two sides are touching") other teachers focus on rather general pedagogical aspects (such as the mode of classroom interaction chosen by the teacher in the categories "Lack of student-to-student interaction" or the teacher's decision about the amount

Table 2 Classification of inductive categories and frequency analysis

Category name and description	Observability in the video	Number of occurrences	Perspective	Number of occurrences
The teacher's example in the introduction	Observable and part of the main action	66	Mathematical didactics aspects	235
At least two sides are touching				
More than five squares as working material				
Pentomino examples on the poster	Observable but not part of the main action	11		
Missing clarification of preceding figures	Not observable and not part of the main plot	158		
Missing visual example and/or counterexample				
Manageability of didactic material				
Pentominoes consist of five squares				
Pentominoes' name				
The abstract teacher's description				
Incomprehension of congruence				
Color highlighting the Pentomino examples	Observable but not part of the main plot	4	General pedagogical aspect	65
Missing response to students' questions	Not observable and not part of the main plot	61		
Lack of student-to-student interaction				
Missing student activities				
Ensuring students' comprehension				
Missing motivation				
Answer does not refer to the question		15		15

of student participation in the category "Missing students activities"). Here, the categories do not refer as much to the mathematical basis of the student's mistakes but conclude that specific (missing) aspects of the lesson's design may have caused the girl's errors. These classifications of categories are presented in Table 2.

The table shows that there are more categories about aspects that are not directly observable in the video, and this applies to mathematical didactics as well as to general pedagogical ones. These categories are results from interpreting the classroom events. This refers to 12 of the 18 categories. Moreover, 219 of the 300 mentioned aspects (235 mathematical didactics and 65 general pedagogical ones) belong to this classification (73%). 66 teachers' answers (22%) refer to aspects that are directly observable in the video and are also part of the main plot. Three categories belong to this classification. Finally, aspects that are observable in the video but not part of the main plot belong to the two categories "Color highlighting the Pentomino examples" and "Pentomino examples on the Poster". These categories are mentioned in only 15 of the teachers' answers (5%). In the following analyses, the observability of aspects will be taken into consideration as a numerical value. In this regard and considering the assumption that novice teachers predominately mention surface characteristics, aspects that are observable in the video and part of the main plot are coded as "0", aspects that are observable but not part of the main plot as "1" and aspects that result from interpreting process as "2".

In order to clarify whether these differences may be related to the teachers' different knowledge bases, Table 3 shows the mathematical didactics categories that resulted from the reducing process. For each category, the table shows the average estimate of the MCK (Mathematics Content Knowledge) and MPCK (Mathematics Pedagogical Content Knowledge) scores of all teachers who mentioned that category in their answers. Table 4 shows that connection between general pedagogical categories and teachers' average estimate of the MPCK and GPK (General Pedagogical Knowledge). The following analysis aims at identifying connections between teachers' noticing (in this case represented by their perception and interpretation) and their professional knowledge. Here, average scores of teachers' knowledge are presented for each of the categories in order to find out whether there are categories (resulting from expert teachers' noticing) that may be mentioned by teachers with higher professional knowledge and vice versa. In Tables 3 and 4, all average scores are colored light grey that significantly lie above the average score of the entire sample of German primary teachers, dark grey if it significantly lies below.

The results displayed in Tables 3 and 4 show that the relation between the categories and the teachers' professional knowledge is variable and not stable. Some of the categories that focus on mathematical didactics aspects of the teaching sequence (Table 3) were mentioned by teachers with over-average MPCK and MCK ("The teachers example in the introduction", "missing clarification of preceding figures" as well as "Incomprehension of congruency") while other categories were named by teachers with under-average MPCK and MCK ("Pentomino's name"). With regard to categories that focus on general pedagogical aspects of the teaching sequence (Table 4) there was only one category that was named by teachers with above-average knowledge (Color highlighting the Pentomino example) and one category that teachers mentioned who had under-average MPCK and GPK (Missing student-to-student interaction).

Analyzing the categories that were mentioned by teachers with rather low professional knowledge shows that those categories describe aspects of the teaching

Table 3 Contingency analysis between the mathematical didactics categories from the inductive codes and teachers' professional knowledge

Categories' names	Observability	N	Mean value MCK	Sign. (2-tailed)	Standard deviation	N	Mean value MPCK	Sign. (2-tailed)	Standard deviation
The teacher's example in the introduction	0	38	555	p < .05	115.1	38	552	p < .05	84.8
At least one side in common		12	516		105.6	12	518		79.1
More than five squares as working material		3	514	p < .05	46.7	3	561	p < .005	49.4
Pentomino examples on the poster	1	9	533		55.6	9	568	p < .0005	64.8
The abstract teacher's description	2	38	550		115.4	38	545		95.4
Missing clarification of preceding figures		10	572	p < .00005	79.2	10	555	p < .05	74.8
Missing visual example and/or counterexample		32	554	p < .05	107.3	32	538		84.2
Manageability of material		4	538		38.3	4	551	p < .05	40.8
Pentominos consist of five squares		4	513	p < .05	51	4	581	p < .00005	45.1
Incomprehension of congruence		38	567	p < .0005	92.3	38	559	p < .005	67.6
Pentominos' name		3	480	p < .00005	74.9	3	486	p < .00005	24.9
Total		214	545		99.7	214	544		82.4

sequence that do not directly relate to the student's errors. For example, the awareness of the figures' names ('Pentominoes') does not affect the solution process which is dominated by the missing consideration of congruency and using only one Tetromino as the basis. The girl could be able to find all existing figures if she knew the building requirements of the figures and understood the concept of congruency. However, she does not need to know the name of the figures, and this category does not relate to the girl's errors. However, it is true that the teacher introduces the figures and their name only very shortly and does not provide enough time for the student to learn the complex name "Pentomino" or to discover the meaning of it. Therefore, teachers who named this category obviously noticed a specific teaching decision that they did not agree with or they would have done differently. However, this category does not explain the girl's errors.

Analyzing the category "Missing student-to-student interaction" results in similar conclusions. It is true that the teacher in the video chose to let the students work for themselves and did not offer opportunities for student-to-student interaction. It is

Table 4 Contingency analysis between the general pedagogical categories from the inductive codes and teachers' professional knowledge

Categories' names	Observability	N	Mean value MPCK	Sign. (2-tailed)	Standard deviation	N	Mean value GPK	Sign. (2-tailed)	Standard deviation
Ensuring students' comprehension	1	14	531		42.1	15	651		79.1
Missing student activities	2	15	549		66.5	16	637		79.1
Missing motivation		2	523		43.6	2	637		47.6
Missing response to students' questions		12	519		113.4	13	657		75
Color highlighting the Pentomino examples		3	576	$p < .0005$	71.4	4	666	$p < .05$	40.2
Missing student-to-student interactions		5	462	$p < .0005$	126.4	4	620	$p < .005$	114.7
Total		51	529		82.3	54	647		75.7

possible that other students did not make the same mistakes as the girl, and student-to-student interaction could have resulted in the girl correcting her mistakes due to the interaction. However, this does not provide possible reasons for the girl's errors as inquired by the question. In addition, the other students followed the same introduction as the girl and might have made the same mistake. Again, teachers noticed an element in the teaching situation (the missing group work) that they would probably include into their own teaching. However, this was not linked to the student's understanding.

The categories named by teachers with average knowledge, have a close connection to the girl's errors. Indeed, the girl does not consider congruency (category "Incomprehension of congruency") and the teacher in the video shows only Pentomino examples that are based on the one specific Tetromino that the girl uses exclusively to construct her figures (categories "The teacher's example in the introduction" and "Examples on the Poster"). In addition, the teacher's organizational decisions that may have caused the error are addressed in the category "Missing clarification of preceding figures". If the teacher discussed the preceding figures in class, this specific error might not have happened.

Overall, it appears that some categories are not linked to the girl's errors while other categories refer to them closely. Tables 3 and 4 show that, for this specific situation, teachers who were able to notice relevant teaching instances and made connections between these specific instances and the girl's learning, often had above-average knowledge. Here, noticing teaching instances as problematic for the understanding and learning of students becomes obvious as one main aspect of teachers' expertise. In an additional analysis, the observability was correlated with the teachers' knowledge scores. However, this analysis did not show significant connections.

Table 5 Contingency analysis between the amount of mathematical didactics aspects noticed and the professional knowledge

Number of didactical aspects	N	Mean value MCK	Sign. (2-tailed)	Standard deviation	N	Mean value MPCK	Sign. (2-tailed)	Standard deviation
0	1	564	$p < .005$	.	1	441	$p < .00005$	.
1	16	509	$p < .05$	128.3	16	515	$p < .05$	120.9
2	33	543		73.8	33	548		65.4
3	21	547		99.3	21	533		92.3
4	9	518		37.2	9	536		27.5
5	3	437	$p < .00005$	62.2	3	534		48.3
Total	83	531		91.3	83	535		82.5

In addition to the accuracy of teacher noticing, its complexity and multi-facetted nature may be a characteristic of teachers' expertise. In this regard, the following analyses link the amount of aspects listed by the teachers (as an indication of teachers' wide-ranging perception) and their professional knowledge. Table 5 shows these relations for the amount of mathematical didactics aspects mentioned by the teachers, Table 6 provides that information for the general pedagogical aspects.

Table 5 shows the relation between the number of didactical aspects that the teachers mentioned and their mean value of MCK and MPCK. This analysis may be a first indication that novice teachers mention only few aspects because the teachers who mentioned only one or less didactical aspects have under-average MPCK. Regarding the contingency analysis between the number of pedagogical aspects mentioned by the teachers and their professional knowledge Table 6 shows that teachers addressing the most pedagogical aspects (in this specific case this amounts to two aspects) have above-average MPCK. This may be a first indication that expert teachers notice a variety of different aspects. However, no significant correlations were found between the number of the didactical aspects and the teachers' knowledge scores, nor between the number of pedagogical aspects and the teachers' knowledge scores.

Table 6 Contingency analysis between the amount of general pedagogical aspects noticed and the professional knowledge

Number of pedagogical aspects	N	Mean value MPCK	Sign. (2-tailed)	Standard deviation	N	Mean value GPK	Sign. (2-tailed)	Standard deviation
0	39	549		84.2	38	646		95.3
1	31	508	$p < .005$	87	31	652		82.2
2	31	556	$p < .05$	45.7	12	638		66.9
Total	83	535		82.5	81	647		85.9

Summary, Discussion and Conclusions

With the aim to analyze how video as a tool for representing classroom practice can help to investigate aspects of teachers' expertise, the video instrument of the TEDS-Follow-Up study served as an example of analyzing what teachers notice and how accurate they are in analyzing important classroom incidents, i.e. those classroom incidents that may have caused the student's errors. In the study described, 131 primary mathematics teachers analyzed possible causes for one student's errors that were presented in one video-vignette. This specific task was selected for the analyses because it required the teachers to analyze the entire teaching sequence and link specific aspects to the student's understanding. The qualitative analysis resulted in 17 categories that show the diversity of aspects mentioned by the teachers. The aspects that are central in the categories analyzed refer either to objects and incidents that were directly observable in the video and were also part of the main action, while other aspects were observable but not part of the main action and even other aspects were a result of interpretation processes and were not observable and not part of the main action in the video. Analyses showed that the most mentioned categories were the interpretative ones, second most common, were aspects that were directly observable in the video, and the least often mentioned were aspects that were observable but not part of the main action. Contingency analyses between the categories and teachers' professional knowledge showed that categories directly linked to the student's errors corresponded with above-average knowledge, while categories that were not the cause of the errors but represented weaknesses of the teaching sequence shown in the video were connected with below-average knowledge. Finally, a connection between high knowledge and noticing a variety of aspects in the teaching sequence was indicated but could not be confirmed quantitatively.

The analyses showed that video as a tool for representing practice can offer - to a specific extent - the multifaceted activities that also occur in real classes. The great amount of categories as well as the different perspectives that the teachers chose in their answers provided evidence that teachers noticed very different things in the same (3-minutes!) video while referring to the same question. With regard to teachers' expertise, it became clear that some teachers noticed crucial aspects for the learning of students while other teachers perceived rather surface characteristics such as the working arrangement in class (individual instead of group work) that are not directly relevant for the students' understanding (cf. Berliner 2001). In addition, and in accordance with the findings of Sabers et al. (1991), the results showed that expert teachers analyzed the reasons for the errors in greater depth—categories that were directly linked to the student's errors were named by teachers with comparatively high knowledge. As Van Es (2011) pointed out, teachers at the lower stages in the Learning to Notice Framework more often attended only to the teacher's pedagogy without linking it to subject-based reflections. Many of the categories that evolved in the present analyses, also focus on the teacher's pedagogy such as her decision on work arrangement ("Lack of student-to-student interaction"), her coloring of the Pentominoes ("Color highlighting the Pentomino examples"), her waiver of student activities and answering student questions ("Missing students' activity" and "Missing response to students' questions") or that she did not ensure the student's understanding of the work assignment ("Ensuring students' understanding"). Most of these categories that focused on the teacher's pedagogy were not directly linked to the student's errors because they were not subject-related and, therefore, did not refer to the student's mathematical thinking.

Focusing on the connections between teachers' noticing and their professional knowledge, the findings suggest that high professional knowledge is linked to noticing crucial aspects of student learning. However, and in accordance with findings from other studies (e.g. Dreher and Kuntze 2015), the results did not indicate that the categories that were more subject-related are linked to high subject-specific knowledge, while categories with a general pedagogical focus are linked to high general pedagogical knowledge. For this specific teaching incidence —analyzing instruction with regard to students' understanding—it showed that teachers with high professional knowledge (subject-specific *and* general pedagogical) identified crucial elements while teachers with low professional knowledge focused on elements that they observed and clarified as insufficient but they were not able to relate them to the student's understanding.

However, critically reflecting on the video instrument and its potential to assess teachers' professional competencies, involves reflecting on what the participating teachers analyzed, evaluated and judged in a teaching sequence with unknown students. The participating teachers did not have the same background knowledge about the students, their behavior and prior knowledge as they would have had from their own class. Since the videos were scripted and edited, teacher noticing was assessed in very condensed situations, where significant things happened in a very short time. Although our qualitative analysis yielded interesting results, interviewing teachers about this specific question, using the video as prompt, might result in even richer variety of categories.

In general the analyses pointed out that the relation between teachers' professional knowledge and noticing facets of professional competencies are not as clear-cut as our study assumed at the beginning. Further analyses with broader instruments are necessary in order to come to more secure results. However, these analyses showed that video as a tool for representing practice can help to investigate aspects of teacher expertise, such as noticing crucial aspects of students' learning.

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