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# Preface for the Special Issue on "Video-Based Research on Teacher Expertise"

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## Objective and Significance of This Special Issue

### Objective

The objective of this special issue is to draw on video-based research to model the nature of mathematics and science teachers' expertise. Expertise is understood as "experts' masterful performance" (Li & Kaiser, 2011a, b, p. 3), which can be conceptualized either as "a cognitive modeling approach that focuses on classroom instruction process" or as "knowledge system perspective that tends to specify knowledge components of teachers' expertise" (Li & Kaiser, 2011a, b, p. 7). Based on this perspective, studies are included that apply complex and innovative sets of video-based assessment instruments covering characteristics identified as typical for (teacher) experts, such as knowledge, perception, accuracy, and speed. Video records render a teacher's recorded classroom practice available for assessment. Alternatively, video-based assessment that require teachers to perceive typical classroom situations presented in video clips are, for example, able to capture many of the complex characteristics of teacher expertise highly efficiently. Other facets of expertise can be examined with speed tests in which teachers have to identify student misconceptions or react quickly to suggest instructional responses to a recorded student action or statement.

The challenge of research on teacher expertise is to come using the chosen evaluation instrument close to real classroom situations, i.e., include in the instrument prospective tasks of the teacher in everyday teaching such as generating teaching strategies or developing teaching tasks and evaluating possible student errors. Most of the expertise research has relied either on retrospective, think-aloud case studies or

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on process-related measures like verbal protocols, but not on standardized assessments of large samples of teachers engaged in the act of teaching. There is an urgent need of methodologically innovative studies that document and evaluate competent teaching under controlled conditions. Such laboratory-like data could provide important information on the internal cognitive structure of teacher expertise:

- How are the different characteristics of teacher expertise interconnected and mutually affording?
- What is the structure of teacher expertise? Is it organized into domain-specific components or are there other organizing principles governing the structure of teacher expertise?
- How is teacher expertise performed in the classroom? Do the teacher's observable acts constitute expertise or are they more effectively thought of as indicators of forms of expertise that are actually cognitive or metacognitive in character?
- Is teacher expertise predictive of student achievement? Teacher effectiveness can be fairly assessed by attributable improvements in student achievement, but does teacher expertise equate to effectiveness or predict effectiveness?

Research designs must emerge whereby teacher expertise can be studied in situ or close to it, rather than as a matter of tenuous inference from indirect measures. For some time now, video has offered an entry point into simulating and studying the classroom enactment of teacher expertise or, from another perspective, of the classroom consequences of teacher expertise. Classroom events can be seen either as vehicles for prompting the performance of teacher expertise or as consequences of its deployment.

In order to provide answers for these central questions, this special issue has been developed, in which papers present research on the use of video to assess teacher competence.

The value of having an approach to the empirical documentation of teaching expertise (or competence) via video-based assessments is that the results can help to clarify how teacher competence is conceived in theoretical and operational terms. Video grounds any consideration of teacher competence in the specific details of classroom context and makes visible any problematic connections between theory and practice. The possibility of teachers reacting to video vignettes or video records of teaching practice immediately problematizes research designs based solely on retrospective self-reports of teachers' beliefs or practice, if there is no significant correlation between these measures. Even the assessment of "teacher knowledge" becomes problematic if we ask the question "With what practical consequence?" and the correlation between results from measuring both knowledge and outcomes is low. Is teacher competence then, in fact, the performative realization of teacher knowledge or are there more useful ways to conceptualize and research teacher competence that connect teacher knowledge more productively with teacher expertise?

Part of de Groot's (1946/1978) early definition of expertise was its limitation to one domain. Empirically, if the situation presented to the chess experts and novices was completely new to both groups, none of them was able to succeed. This suggested a high level of domain-specificity to the performance of expertise and requires teacher research to be domain-specific as well. Shulman (1986, p. 6) described this domain-specificity of expertise as "the missing paradigm" in cognitive research. He called into question the generalizability of research results. Piaget's theory of cognitive development, for example, was meant to be universally valid. In contrast, expertise research provided evidence that experts are not able to transfer their speed and accuracy from one domain to another (Glaser & Chi, 1988). Neither mental speed, basic memory, nor intelligence were different between experts and novices in fields completely new to them (Ericsson, 2005). Extrapolation of these findings to the context of instructional practice suggests that teacher competence should also be viewed as related to the content of instruction.

### Significance

High-quality student achievement in mathematics and science depends on high-quality teaching. In order to support the development of teacher expertise, it is necessary to learn more about its nature and how it might be assessed and promoted. Only when we know more about the cognitive structure of teacher expertise and its performative correlates will it be possible to study its enactment in actual classrooms and design professional development activities tailored to support individual mathematics and science teachers' developmental needs. In particular, the contributions of en/action and reflection to teacher learning (Clarke & Hollingsworth, 2002) and their interaction can then be studied in situ and in detail.

To identify the domain-specificity of teacher expertise and the relationship between teacher expertise, teacher performance and student achievement substantially enriches the state of research on the nature of teacher expertise. This is an urgent and ongoing need of expertise research that has been frequently pointed out in the recent literature (Williams & Ericsson, 2008). Based on the results of such research, conclusions could then be drawn for further directions of expertise research and the design of professional development activities (cf. Krainer, 2015), in which didacticians should play an important role (Coles, 2014; Tirosh, Tsamir, Levenson, Barkai & Tabach, 2014).

A feature of this special issue that is distinctive in comparison with existing research is the integration and connection of different attempts to capture the complexity of teaching and the more focused activity of assessing teaching practice. The literature on video-based classroom research and teacher competencies has identified many of the dimensions about which assessment might be conducted but operationalizing these dimensions (and the associated descriptive frameworks) into practicable protocols, categories, and metrics and then connecting these to valued outcomes is a new frontier that this special issue addresses.

## Conceptual Framework

There is some agreement within expertise research on the core characteristics of teachers who can be regarded as experts in the classroom compared to novices (Berliner, 2001; Chi, 2011). Expert teachers perceive and interpret classroom situations faster, more accurately, and more holistically than novice teachers. Expert teachers are also able to anticipate a larger variety of potential consequences of a classroom situation, in particular with respect to critical incidents, and they make use of a richer repertoire of strategies regarding how to react. Experts predict more quickly and more correctly what will happen and they analyze instructional processes with greater emphasis on student learning than on their own teaching methods (Smith & Strahan, 2004).

It takes many years of training, practical experience, and purposeful practice before a teacher develops from a novice into such an expert. Ten years of training, deliberate practice, and practical experience is a threshold often mentioned in the literature as crucial for the development of expertise (Ericsson, Charness, Feltovich & Hoffman, 2006). During this time, the teacher's knowledge is reorganized so that it becomes more extensive than that of novices and its different facets are better linked to each other (Livingston & Borko, 1989).

Ever since the ground-breaking study on chess performance by de Groot (1946/1978), the definition of an expert has been described by long-lasting high-quality performance compared to others. de Groot instructed chess experts, identified through outstanding success in national and international competitions, to think aloud while they selected their next move and he showed that they were better able to select moves than novices. The work of Sweller and his colleagues has extrapolated this research into the context of problem solving expertise and associated instructional practice (e.g. Sweller, 1992). Expertise in this framework is identified with the capacity to implement optimal actions through recognition of previously encountered situations.

Expertise is particularly evident in situations that are not clearly defined, with a lot of action going on at the same time, and which occur at high speed (Berliner, 2001). The set of knowledge an expert has to draw on can therefore not be predicted completely beforehand, as Hatch pointed out with respect to the teaching profession (1999, p. 236): "Each community, school, and classroom is different. Each teacher brings his or her own experience, disposition, and expertise to the teaching setting."

Typical for situations in which experts work is that the several incidents going on in parallel to each other are interpreted analytically in a step-wise manner and may be interpreted differently by the individual actors involved. In formulating a response to such overlapping incidents, the teacher has to make a decision regarding what is really important, where to focus and how to react. These decisions depend on the context, including the history of the participants, and may require deviation from the teacher's initial objective for a lesson. Job requirements of teachers are therefore different compared to other academic professions like engineering (Neuweg, 1999). If an engineer has to build a bridge, even suddenly emerging problems can usually be defined and addressed in a more systematic way.

The development of expertise seems to be a process with more or less distinct stages that depends on many intervening factors such as prior systematic knowledge, training opportunities, practical experiences, and support. Based on the state of research, at least three facets of expertise can be distinguished (Glaser & Chi, 1988; Li & Kaiser, 2011a, b):

1. The perception of a situation and the repertoire of strategies to react
2. The speed of recognition and memory
3. The knowledge underlying the first two facets

With these facets, the cognitive foundation of classroom performance and its situated nature are taken into account at the same time—two important differences to the previous product-function model dominating psychological research (Bromme, 2008).

With respect to knowledge as one facet of expertise, the literature suggests that experts have more knowledge than novices. We set to one side for the moment, the question of what form this knowledge might take. Important for expertise is the extent of knowledge on the one hand and its mental representation, how it is organized, and the flexibility with which it can be applied to complex situations on the other hand (Hoffman, 1996). Experts have more extensive knowledge and it is more accurate (Livingston & Borko, 1989). The connective process between short-term and long-term memory functions more efficiently and the problem representation of experts is deeper and more articulated in contrast to novices, who tend to build superficial and literal representations derived from keywords or visual configurations (Rikers & Paas, 2005; Chi, Glaser & Rees, 1982).

Based on their knowledge repertoire, experts design their instruction to be well-aligned with their objectives and these are oriented toward the students and their learning outcomes *for which they take responsibility* (Carter, Cushing, Sabers, Stein & Berliner, 1988; Smith & Strahan, 2004). In this process, experts connect the content to be taught with the needs of their students and the classroom. Specifically, with respect to mathematics teachers, Schoenfeld & Kilpatrick (2008) pointed out that the amount and understanding of school mathematics increases, together with the teacher's repertoire of teaching strategies, through practical experiences.

Besides relying on a rich knowledge base (cf. Rowland, Turner & Thwaites, 2014), experts perceive situations more accurately because they can anchor new information in a well-structured repertoire of knowledge, e.g., by chunking events or categorizing the cues perceived (Clark & Lampert, 1986). Thus, they are able to store information in their long-term memory and then recall it more accurately (Carter et al., 1988). We have information about these mechanisms from several fields. Weissensteiner, Abernethy, Farrow & Müller (2008), for example, had cricket players watch a film with ball movements. The anticipation of ball types and trajectory discriminated well between experts and novices.

Chase & Simon (1973) developed the "Chunking Theory" that explained the cognitive mechanisms underlying the development of expertise. With extended experience, experts are able to retrieve actions similar to prior actions because they recognize the pattern. Experts have acquired a large number of complex patterns during a long time of engagement (Ericsson, 2005), which they extract using perceptual cues developed during prior experience. Gobet (2005, p. 184) calls this ability the "professional eye" of experts. This means that experts do not just automatically extract patterns and retrieve their responses but select the relevant information from working memory (Ericsson & Lehmann, 1996). Thus, the information is accessible during planning and reasoning about alternative courses of action so that experts can adjust to changing circumstances and anticipate further events in advance. Video-based research is well placed to take on the challenge of documenting the performative consequences of such expertise. And video material can be used as stimulus to examine teachers' capacity to quickly identify possible alternative courses of action in response to specific classroom situations or events.

This Chunking Theory was supplemented by Gobet & Simon (1996), who pointed out the necessity of schemes, sometimes also called templates, built on a higher level of abstraction by connecting several cues to each other and including not only fixed information in terms of chunks but also variable information. Thus, experts can also deal more easily with situations, even though they may contain new information not experienced before (Gobet, 2005). Finally, Ericsson & Kintsch (1995) complemented other advances in expertise research by filling in the role of long-term working memory. Since short-term memory by its nature is limited, it is of outmost importance to deliver new information effectively to long-term memory. Superior retention is based on organized patterns of information. Experts' superior ability consists primarily of this capacity, so that they are able to anticipate, plan, evaluate, and reason efficiently and effectively. This means that experts exploit prior knowledge to durably encode information and form more elaborate representations as they accumulate new experiences.

In addition to (or as a consequence of) their superior perceptual and interpretive abilities, experts are more likely to find an appropriate solution for a critical incident. Therefore, they can do more in less time (Sternberg & Horvath, 1995). With respect to the repertoire of strategies to act, teachers are novices before acquiring practical experience, and their practice is restricted to the use of systematic (declarative) knowledge gained at the university. After a few years, their knowledge has been restructured, so that they have a repertoire of effective responses to most situations and finally also have routines for rare critical incidents. Based on their expert knowledge, they are able, even in most pressing situations, to build an appropriate mental model of what is going on in the classroom, both in relation to the content and with respect to pedagogical challenges like classroom management, and then to focus on what is most important for effective action in a given situation (Leinhardt, 1993). Such capabilities as the recognition of the salient features of situation, the identification of possible alternative actions, and the formulation of optimally effective action plans are all amenable to study in situ in video records of the classrooms of expert teachers or through video-stimulated clinical interviews with expert and novice teachers.

Thus, by virtue of their extensive experience, expert teachers reduce the pressure of continual cognitive demand and are able to perform tasks effortlessly that novices can perform only with effort. Although both experts and novices apply knowledge and analysis to solve problems, experts are more likely to arrive at creative solutions to those problems, solutions that are both novel and appropriate. Expert teachers do not simply solve the problem at hand; they often redefine the problem and thereby reach ingenious and insightful solutions that do not occur to others. This flexibility of thought has long been identified with expert problem solvers (e.g. Krutetskii, 1976). A variety of contemporary research strategies, such as post-lesson video-stimulated interviews (e.g. Clarke, 2006), have the capacity to unpack teacher decision-making at such critical moments.

Besides relying on a rich knowledge base and perceiving classroom situations more accurately and with more ideas on how to react, experts perceive such situations faster and can make rapid judgments (Clark & Lampert, 1986). The information perceived is rapidly processed through their cognitive network in which relevant knowledge is stored as chunks. With extended experience, experts approach their short-term memory more speedily and they are able to retrieve information quickly because they recognize the pattern even if the action is presented only for a brief period of time. The findings of expertise research are sound and stable across many professions such as chess, sports, or medicine (Ericsson, 1996). It is the intention of this special issue to bring together reports of video-based research that will provide a comparable empirical foundation on teacher expertise in the contexts of mathematics and science.

## Overview of the Papers in This Special Issue

The ten papers of this special issue of IJSME on "Video-Based Research on Teacher Expertise" can be assigned to two strands of the discourse: in the first strand, videos are used as assessment tools, whereas in the second one, visual records are used as data in assessment processes.

### Using Video as Assessment Tools

Six papers belong to this first strand which not only share the same methodological approach by using videos as assessment tools but also rely on a similar theoretical perspective. Video-based assessments of teachers' skills to perceive classroom situations and to make decisions about how to proceed in these situations are regarded as indicators of teachers' competencies closely related to performance in real classroom situations. These six papers cover the full range of school levels from preschool to secondary school, both mathematics and science classrooms as well as content-specific and general pedagogical research questions.

The first paper by Dunekacke, Jenßen & Blömeke (2015) presents a video-based test instrument that can be used to assess prospective preschool teachers. The authors examine to what extent these teachers' mathematics content knowledge predicts their mathematics-specific perception and decision-making skills.

The second paper by Blömeke, Hoth, Döhrmann, Busse, Kaiser & König (2015) describes a video-based test instrument that can be used to assess practicing primary school teachers' skills. The authors examine to what extent teachers' knowledge and working conditions predict their perception and decision-making skills. Both content-specific and general pedagogical perspectives are included.

Knievel, Lindmeier & Heinze (2015) also present a video-based test instrument that can be used to assess practicing mathematics primary teachers' skills. This third paper discusses among others the reliability and validity of this instrument.

The fourth paper by König, Blömeke & Kaiser (2015) describes and analyses a video-based test instrument that can be used to assess practicing secondary school teachers' skills. The authors examine to what extent teacher education as well as teachers' practical teaching experiences and working conditions predict their general pedagogical perception and decision-making skills.

Two papers dealing with more general research questions in the context of video-based assessments close this first strand of the special issue and refer to special aspects and problems, which have been discussed in the preceding papers.

Steffensky, Gold, Holodynski & Möller (2015) examine whether perception and decision-making skills play out the same way with respect to content-specific and general pedagogical classroom situations or whether it is necessary to distinguish between these. They use a video-based test instrument with prospective and practicing science education primary teachers' skills.

Kaiser, Busse, Hoth, König & Blömeke (2015) discuss the complexities of video-based assessments from a theoretical and a methodological perspective. They demonstrate how it is possible to overcome shortcomings of current research on teachers' competence.

Using Visual Records as Data About Classroom Practices

Four papers belong to the second strand, which use recorded classroom practices as data for assessment purposes. These data are analyzed or provide stimuli for interviews. The four papers cover primary and secondary education, both mathematics and science teachers as well as content-specific and general pedagogical research questions.

The first paper in this part by Cortina, Miller, McKenzie, Epstein & Feng (2015) presents a promising new approach to recording classroom practices. They use mobile eye-tracking with expert and novice teachers to examine the relation of such low-inference data to classroom observations which need high inferences.

The second paper by Gotwals, Philhower, Cisterna & Bennett (2015) analyzes videotaped classroom practices. Based on these videos, the authors examine formative assessment practices of mathematics and science teachers.

The third paper by Tytler & Aranda (2015) also used recorded video data to analyze science primary teachers' classroom discourses. In a comparative study, Tytler and Aranda analyze teachers' discursive moves in responding to student input across three countries.

The fourth paper by Ruhrig & Höttecke (2015) reconstructs science teachers' competence in dealing with uncertainty with semi-structured interviews and video vignettes as stimuli. The vignettes illustrated situations in which uncertainty was unexpectedly aroused during science teaching.

Overall, the ten papers of this special issue provide insights into the current state of research about video-based assessments to mathematics and science education. This issue goes beyond the methodological restrictions of earlier studies and presents innovative research designs and instruments, which allow to evaluate teacher expertise in situ or close to it. In addition to these methodologically innovative studies, the issue provides the reader with innovative research results on teachers' expertise in mathematics or science based on video or visual data.

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