2.2 Analyses and Validation of Central Assessment Instruments of the Research Program TEDS-M

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Abstract

The TEDS-Validate project has been carried out within the research program derived from Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M). In this chapter, we describe the aim of the study, which is related to the question of whether research findings brought forward by measurement instruments to test professional competence of mathematics teachers have predictive validity for the quality of their classroom instruction and the learning gains of their students. Based on this, we question whether situation-specific skills (measured via video-based assessments) contribute to explain instructional quality and learning gains of students – in addition to the effects of professional knowledge of teachers. To answer the research questions, data was collected in Thuringia, Saxony and Hesse from 2016 to 2019 with a survey of 113 in-service teachers. They were tested using web-based instruments to capture their mathematics, mathematics pedagogical and general pedagogical knowledge as well as their noticing competencies. TEDS-Validate points out the broad applicability of the instruments for the comprehensive measurement of mathematics teachers competencies. To evaluate the effects of prospective teachers' practical activities during their school practicum within the master study of initial teacher education, these instruments will be applied in a follow-up transfer project.

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Keywords

Mathematics teachers' competencies, teachers' knowledge, noticing, instructional quality, students learning gains, international comparative studies, transfer activities

1 Introduction

TEDS-Validate has been carried out within the research program, which has been derived from the international comparative study on teacher education, the *Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M)* (2008–2010) (Blömeke et al. 2010a, b). The design, conceptualisation and instruments of TEDS-Validate refer to the TEDS-M research program and has evolved in the last ten years.

1.1 Aims of the TEDS-Validate Project

The TEDS-Validate project aims to answer the question of whether research findings brought forward by TEDS-M measurement instruments to test professional competence of mathematics teachers have predictive validity for the quality of their classroom instruction and the learning gains of their students. The used instruments have been developed within the study TEDS-M and measure the professional competencies of prospective mathematics teachers. It is assumed that if predictive validity of the instruments of teachers' competencies on quality-oriented teaching and students' learning gains can be confirmed, then these assessment instrument can be considered objective, reliable, and valid and enable examination of teacher effectiveness in future research. The measurement instruments developed within TEDS-M, which consisted of teachers' knowledge instruments and capture the central cognitive elements of mathematics teachers' professional competence (Shulman 1987, Baumert and Kunter 2006), were already validated: mathematical content knowledge (MCK), mathematical pedagogical content knowledge (MPCK), and general pedagogical knowledge (GPK). However, it is still an open question whether these instruments fulfil predictive validity concerning the mastering of professional tasks relevant during teaching as the core task of teachers.

Another objective of the TEDS-Validate project was to analyze which kinds of teacher knowledge – declarative ("knowing that…") or procedural ("knowing how…") – are acquired during initial teacher education and teachers' profession-

al practice. The original TEDS-M measurement instruments (e.g., Buchholtz et al. 2016; König and Blömeke 2010) were mainly focused on declarative cognitive knowledge, which is acquired during initial teacher education and are an essential part of teacher's knowledge for teaching. Procedural knowledge relies strongly on practical experience, being more related to teaching situations and performance in class. This part of the overall teachers' competencies was evaluated by specific further development of the original TEDS-M-instruments, namely video-based assessment from the project TEDS-Follow-up (TEDS-FU) (e.g., Blömeke et al. 2014; König et al. 2014). These innovative assessment instruments were evaluated by expert reviews and have been proven to be reliable and valid as well as being suitable for capturing situation-specific skills. The additional question within TEDS-Validate was whether these instruments also have predictive validity, which would allow to gain deeper insight for the design of initial teacher education.

The international discourse on professional competence developed during initial teacher education or professional development has strong gaps. Although a chain of effects such as teacher preparation – teacher competence – instructional quality – students' learning gains is generally assumed (e.g. Baumert et al. 2010, Hill et al. 2005), there is only little empirical evidence whether competencies teacher acquire during initial teacher education have an influence on the quality of their instruction and the learning gains of their students. Especially the relationship of teacher sub-facets of their competencies such as CK, PCK, and GPK on instructional quality and student learning has not yet been modelled simultaneously, neither have situation-specific cognitive skills been accounted for.

1.2 Research Questions

In the TEDS-Validate project, two major research questions were guiding the empirical study:

1. How far can we provide empirical evidence that the measurement instruments developed within the TEDS-M and TEDS-FU projects have predictive validity for teaching mathematics at high quality?

We expect that MCK, MPCK, and GPK as well as video-based measures significantly impact instructional quality and correlate with the learning gain of students.

2. Do situation-specific skills (measured via video-based assessments) contribute to explain instructional quality and learning gains of students – in addition to

the effects of professional knowledge of teachers (as measured via paper-pencil tests), i.e., do they have added value?

We expect that video-based skills of perception, interpretation, and decision-making correlate higher with instructional quality and student learning gains than knowledge-based tests (MCK, MPCK, GPK). Moreover, we expect that the relationship between video-based measures and students' learning gains will be mediated by instructional quality.

2 Literature Review

2.1 Teacher Competence and Its Measurement

The concept of competence in educational research has been developed within different research traditions. The broad definition developed by Weinert (2001), which incorporates (i) cognitive abilities, (ii) the motivation, volition, social willingness, and ability to solve problems, and (iii) the motivation, volition, and social readiness to implement solutions, has shaped the discussion of competence in large-scale studies on teacher education (Kunter et al. 2011; Blömeke et al. 2010a, b). Klieme and Leutner (2006), who define competencies as situation-specific, cognitive performance dispositions, which are functionally responsive to situations and demands in specific domains, have further developed this work. Within the discussion of professionalization of teachers, generic models of professional competence are currently proposed encompassing cognitive and affective-motivational aspects (Baumert and Kunter 2006; Blömeke 2017). The differentiation of teachers' dispositions into various knowledge facets by the seminal work of Shulman (1987) has shaped the scientific discourse until today (Guerriero 2017). In the last decade, this approach has been widened going beyond the description of teacher competencies as personal traits (i.e., individual dispositions relatively stable across different contexts) including situational facets (Kaiser et al. 2017).

Similar developments can be identified in subject-related discussions on teacher education. For example, in mathematics education, Krainer and Llinares (2010) described various trends in the literature about prospective teachers, practicing teachers, and teacher educators, amongst others reflecting a shift from the individual perspective on teachers toward emphasizing the social dimension in teacher education based on sociological and sociocultural theories. In connection with this shift towards the social dimension different paradigms on teachers' professional competencies have been identified by Rowland and Ruthven (2011), which can

be characterized either as cognitive or as situated approaches to the professional competencies of teachers (for an extensive overview on these paradigmatic distinctions, see Kaiser et al. 2017).

This development towards the social dimension on the professional activities of teachers exhibits the transfer from a cognitive perspective focusing on the knowledge facets of teachers within teacher professionalism to situated approaches. The cognitive perspective has been dominant in recent decades and is characterized by its focus onto a limited number of components related to personal traits. Prominent examples of large-scale studies mainly come from mathematics education, such as the *Teacher Education and Development Study in Mathematics* (TEDS-M) or the *Professional Competence of Teachers, Cognitively Activating Instruction and the Development of Students' Mathematical Literacy* (COACTIV). Follow-up studies of these and other studies consider the multidimensionality of teacher competencies and include context-specific and situated aspects of teaching and learning. Especially the concept of teacher noticing plays an important role. In the newly developed framework of teacher competencies Blömeke et al. (2015) show that older conceptual dichotomies ignore either the stable dispositional or the more variable situational competence facets. According to this model, competencies can be described along a continuum from personal dispositions, namely teacher professional knowledge and beliefs, which are complemented by situation-specific cognitive skills such as perception, interpretation, and decision-making, which finally lead to teacher performance in the classroom.

The research model used in the project TEDS-Validate (Section 3.2.1), refers to this theoretical approach describing professional teacher competencies as blend of cognitive and affective-motivational dispositions as well as situational-specific skills (Blömeke et al. 2015, Kaiser et al. 2017). The different paradigms on the conceptualization of teacher competencies have consequences regarding competence measurement. On the one hand, classical paper-and-pencil tests capturing the different facets of teacher knowledge have been developed, primarily in mathematics education but also within other domains (Großschedl et al. 2015 for biology education, König et al. 2016 for education of English as a foreign language, Krauss et al. 2017 for mathematics, German, English, Latin, physics, music, religious education; see also contributions in this volume). On the other hand a number of research groups referring to teacher noticing or professional vision has developed video-based assessment instruments (e.g., Kersting et al. 2012; Seidel and Stürmer 2014, Kaiser et al. 2015; for an overview of the construct of noticing, see Sherin et al. 2011, more recent Schack et al. 2017, a systematic literature review on the measurement of noticing is provided by Stahnke et al. 2016).

2.2 Research Desiderata Addressed by TEDS-Validate

Studies that analyze teachers' certificates and qualifications in terms of their impact on student learning (e.g., Darling-Hammond et al. 2001; Cochran-Smith and Zeichner 2005; Palardy and Rumberger 2008) have certain limitations. They have been criticized for the fact that the teacher quality indicators used do not sufficiently explain variations in the quality of their teaching or the learning progress of their students. Therefore, researchers have started to design studies that directly assess teacher knowledge, and the indicators for professional competence of teachers are examined, for instance, regarding its relationship to instructional quality and student learning (Hill et al. 2005; Baumert et al. 2010; Kersting et al. 2012).

Measurement instruments for cognitive facets of teacher professional competence have been developed over the past decade with particular focus on mathematics. In Germany, the research study COACTIV (Kunter et al. 2011) is well known, however, its findings are based on data collected 15 years ago. PISA 2003 was extended by a second time point one year later with another student assessment in mathematics, allowing the analysis of student progress in year 9 and 10. Their teachers were assessed using paper-pencil tests measuring CK and PCK and measures were applied to capture the quality of mathematics instruction (Baumert et al. 2010). The COACTIV study proliferated evidence that teachers' CK and PCK effect instructional quality (such as cognitive activation) and influence student learning in mathematics. More recently, data on teachers' noticing skills were related to their knowledge base (Bruckmaier et al. 2016). These findings relate to the international state of art on CK and PCK as brought forward by Hill et al. (2005) in the US context. In the COACTIV-R study in Germany, empirical evidence was provided for the effect of pedagogical-psychological knowledge of pre-service teachers during induction on the instructional quality of classroom management as perceived by students (Voss et al. 2014). In a study conducted in Austria, König and Pflanzl (2016) provided evidence for the effect of TEDS-M test measuring GPK on student perceptions among about 250 in-service teachers. If teachers performed well on the GPK test, students reported higher instructional quality regarding effective classroom management, teacher clarity, and positive teacher-student relationships, even when controlled for teacher personality (Big-Five), teaching experience, and teacher certification grades.

Although these findings are promising towards teacher competence and its relevance for teaching and student learning, there is still a lack of research:

- First, nearly all studies basically assume a chain of effectiveness related to 'teacher education – teacher competence – instructional quality – student learn-

ing'. Although numerous studies have shown pre-service teachers may acquire competencies (e.g., teacher knowledge) during initial teacher education (for a recent overview, see Kaiser and König 2019), hardly any evidence exists as to what extent these teacher competencies acquired during initial teacher education at higher education institutions have an impact in the long run. That means it is still unclear whether teacher competencies that represent an outcome of higher education actually are significant predictors for instructional quality teachers provide during in-service teaching and the progress of their students.

- Second, none of the studies has analyzed the triad of CK, PCK, and GPK in an overall model. So hardly any insight can be given into the multidimensionality of teacher competence and its specific impact on instructional quality and student learning when modelling the triad simultaneously.
- Third, due to recent developments in competence modelling, not only teacher knowledge as a cognitive disposition, but also situation-specific teacher skills have to be considered (Blömeke et al. 2015, Kaiser et al. 2015, 2017). Only very few studies have started to reflect on such a distinction in the complex field of teacher competence measurement (e.g., Blömeke et al. 2016, Kersting et al. 2012, König et al. 2014). These studies again focus on either subject-specific or generic facets of teacher competence, so they have the limitation that they cannot include all facets in an overall statistical model.

TEDS-Validate specifically focuses on these research desiderata. The whole set of measurement instruments developed in the TEDS-M research program, including TEDS-M, TEDS-FU, TEDS-Instruct, have been applied. Therefore, its findings should have relevant implications for teacher education, as teacher education programs usually consist of the typical components related to the subject, subject-specific pedagogy, and general pedagogy (Flores 2016). The differentiation into teacher knowledge and situation-specific skills as cognitive elements of the professional competence of teachers (Figure 1) reflects the ongoing discussion on theory-practice in teacher education, which is of great relevance in the current German Quality Initiative of Teacher Education ([*Qualitätsoffensive Lehrerbildung*], BMBF 2014).

3 Design of the Study

3.1 Overview of the TEDS-M Research Program

The *Teacher Education and Development Study in Mathematics* (TEDS-M) carried out under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) was a comparative study of teacher education and the first IEA study on tertiary education, as well as the first international large-scale assessment of future teachers that based on representative samples (Tatto and Senk 2012). The TEDS-M target population consisted of mathematics teachers for elementary and secondary schools in their final year of teacher education. Data were collected in 2008. A central component of TEDS-M was the measurement of the professional knowledge of prospective teachers. The common international questionnaire only measured prospective teachers' mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK). Three participating countries – the United States, Germany, and Taiwan – therefore carried a national version measuring prospective teachers' GPK. Besides pre-service teacher knowledge, also, their beliefs were investigated and a broad range of institutional characteristics of teacher education programs such as learning opportunities as well as socio-demographic variables were part of the prospective teacher surveys (for details, see Blömeke et al. 2010a, b, 2014).

TEDS-M had a particular impact on starting empirical research on teacher education in Germany. As a consequence, several studies were conducted that systematically built on the TEDS-M research: TEDS-Follow Up (TEDS-FU), TEDS-Learning to Teach (TEDS-LT), and TEDS-Instruct (TEDS-U) building the comprehensive TEDS-M research program (Table 1).

While the TEDS-M study intended to evaluate the efficiency of teacher education at an international level by assessing prospective mathematics teachers' content-related knowledge at the end of teacher education, including the study courses and opportunities to learn, the other TEDS-M-studies had different objectives, respectively. They all were conducted in Germany or in specific federal states of Germany and they focused on different target groups.

Table 1 Studies of the TEDS research program

	TEDS-M	TEDS-LT	TEDS-FU	TEDS-U	TEDS-V
		(Learning to Teach)	(Follow-Up)	(Instruct)	(Validate)
	2006–2010	2008–2012	2010–2013	2015–2018	2016–2019
Geographical focus	international	Bavaria, Baden-Wuerttemberg, Berlin, Hamburg, Hesse, North Rhine-Westphalia	Germany	Hamburg	Hesse, Saxony, Thuringia
Target group	Pre-service teachers in their final year of teacher education	Future teachers at universities	Early career teachers	In-service teachers	
Subject	Mathematics	German, English as a Foreign Language, Mathematics	Mathematics		
Teaching Type	Primary and Secondary	Secondary	Primary and Secondary	Secondary	

- TEDS-LT aimed at transferring the conceptualizations and assessment approaches of TEDS-M to other domains such as German and English as a Foreign Language. TEDS-LT was continued in two more projects on language teacher education: PKE (König et al. 2016) and PlanvoLL-D (see the chapter by König et al. in this volume).
- TEDS-FU as a follow-up study of TEDS-M was more directly linked to TEDS-M, since it re-examined teacher professional competence of those participants who had actually entered the teaching profession four years later. TEDS-FU enriched the knowledge oriented TEDS-M-study by context-specific and situated aspects of teaching and learning including the concept of teacher noticing. TEDS-FU examined the assumption of the multidimensionality of teacher competencies of referring not only to subject-based cognitive aspects but also to pedagogical reflections on the teaching-and-learning situation as a whole. Overall, the context in which teaching and learning are enacted was therefore been brought to the foreground by TEDS-FU.

- TEDS-Instruct (TEDS-Unterricht, TEDS-U) was conducted as a pilot study exploring conceptualizations, instruments, and analyses approaches to be validated in TEDS-Validate. Mathematics teachers recruited for TEDS-Instruct (convenience sample due to data collection constraints) either taught at the academic track (*Gymnasium*) or at the non-academic track (*Stadtteilschule*) in the federal state of Hamburg. Classroom observations with a newly developed instrument were carried out with a subsample of the studied teachers to evaluate the instructional quality of their teaching. For each school class of the participating teachers, student assessment data were made available by the Institute for Educational Monitoring and Quality Development in Hamburg.

3.2 Description of TEDS-Validate: Research Model, Sample, and Instruments

TEDS-Validate builds on previous work done in the TEDS-M research program, in particular, it uses measurement instruments developed in the context of these previous research studies. These were analysed and the validity of these instruments were examined.

To investigate the two major research questions (Section 1.2), a specific research model was developed (Figure 1). It is grounded in relevant paradigms prominent in current empirical educational research such as effective teaching (e.g., Hattie 2009; Helmke 2012) and teacher expertise (Berliner 2004; Stigler and Miller 2018). Referring to current research on instructional quality such as the concept of generic dimensions being relevant for student learning, we included cognitive activation, constructive support, and effective classroom management and extended this framework by subject-specific dimensions on mathematics instructional quality. One basic assumption is that these dimensions of instructional quality significantly contribute to students' learning gains, mediated by learning processes triggered by the teachers. To describe teachers and their role in the teaching-learning-interaction, a particular focus of TEDS-Validate was on a complex model of cognitive elements of professional competence of teachers. Following current ideas in competence modeling by Blömeke et al. (2015), we differentiated into teacher knowledge as being distal cognitive elements and video-based measures of situation-specific skills as being more proximal cognitive elements for teaching. These core elements – teachers, teaching, and students – were framed by background and demographics of both teachers and students as well as context variables such as class composition characteristics or school type.

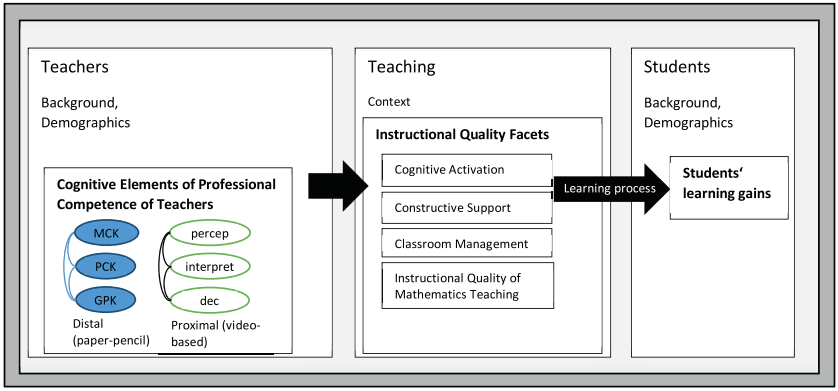

Figure 1 TEDS-Validate research model

TEDS-Validate has been conducted in Thuringia, Saxony and Hesse from 2016 to 2019, 113 in-service teachers participated in the study, 70 (62 %) in Thuringia, 13 (11 %) in Saxony and 30 (27 %) in Hesse. 64 participants (57 %) were female, their average grade in the first state examination was 2.1. (out of a scale ranging from 1 to 4 with 1 indicating highest level and 4 indicating just having passed) with one being the best grade and 1.9 in the second state examination. Their average age was 43 years with a range from 26–64, accordingly their professional experience averaged to 16 years with a range from 0.5–40 years. The evaluation of cognitive and situation-specific tests took 2.5 hours testing time and was carried out online at home by the teachers (using the survey software package and provider 'Unipark'), usually with a break between the two test parts. The teachers in Thuringia received financial incentives in addition to courses for professional development, in Hesse and Saxony only professional development courses as incentives were permitted.

Moreover, instructional quality was evaluated with a sub-group of teachers (n = 39), 20 (51 %) in Thuringia, 5 (13 %) in Saxony and 14 (36 %) in Hesse. 23 participants (59 %) were female, their average grade in the first and second state examination was nearly identical to the whole sample (2.0 and 1.9). Their average age and range was very similar to the whole sample (44 years and 26–64), the same held for their professional experience (average 17 years and a range from 1–40 years). The teachers were observed within their teaching two times by two raters using the newly developed rating instrument (Jentsch et al. under review; Schlesinger et al. 2018). The University of Jena provided the data on students' learning gains through the project 'kompetenztest.de'. Students' learning gains

have been measured via central assessments that regularly take place during grade 6 and 8 in Thuringia and Saxony and which are aligned with the national educational standards for mathematics (https://www.kompetenztest.de/). These data could not be collected in Hesse as no second testing takes place in this federal state.

As TEDS-Validate aimed at proliferating innovative approaches of measuring teacher competence the following instruments developed within the TEDS-M-research program have been used in the study:

- Online measurement instruments for MCK, MPCK, and GPK as the relevant categories of teacher professional knowledge originally stemming from TEDS-M and transferred from paper-pencil-format into online-format (Blömeke et al. 2010a, b, 2014);
- Online instrument on Perception, Interpretation and Decision-Making (PID) in the mathematics classroom using three video-vignettes related to mathematics pedagogy, general pedagogy (Kaiser et al. 2015), and an additional video-based instrument on effective classroom management expertise of teachers (CME, König 2015; König and Kramer 2016);
- Online test on the ability to quickly identify student errors (Pankow et al. 2016);
- In-vivo evaluation of instructional quality using a novel observational instrument (Schlesinger et al. 2018); in addition 15 of the teachers of TEDS-Instruct were video graphed within their original classes to compare the effect of in-vivo-coding and video-based coding (Benecke 2018).

4 Results[1]

In the framework of the TEDS-M research program TEDS-Validate focused on the validation of the conceptualizations and instruments developed within TEDS-M, especially on the predictive validity for teaching mathematics at high quality and the impact of situation-specific sub-competencies of teachers on instructional quality and students' learning gains. Overall, the breadth of the TEDS instruments inventory allowed a complete operationalization of novel understanding of teacher competence as being a continuum comprising cognitive dispositions, situation-specific skills, and performance (Blömeke et al. 2015; Kaiser et al. 2017).

1 In the following core results of TEDS-Validate are presented, although the publication process is still in strong progress.

4.1 Construct Validation of Pedagogical Knowledge

Pedagogical knowledge of teachers is a relevant category of the professional teacher's knowledge base (Shulman 1987; König 2019). The test instrument developed in TEDS-M turned out to be valid for comparative assessment in the US, Germany, and Taiwan (König et al. 2011). The test focuses on pedagogical tasks teachers have to master such as classroom management, dealing with student heterogeneity, or assessment, whereby the knowledge focused on in the test is conceptualised as link to a specific subject. The TEDS-M test has proven to be reliable for measuring the knowledge of pre-service and in-service teachers, based on several studies, and broad evidence of its validity across professional education phases and contexts has been provided (for an overview, see König 2014).

In TEDS-Validate, the examination of the test's construct representation (Embretson 1983) was studied more carefully. The analyses focused on the question whether the test also requires and represents construct-relevant cognitive processes of professionally experienced mathematics teachers. Based on the data of TEDS-Validate, it was examined whether task difficulty could be attributed to cognitive processes as suggested in a proficiency model proposed by König (2009; in addition Klemenz and König 2019). The findings point out that the measurement is reliable among the TEDS-Validate target group of in-service teachers (EAP/PV-reliability .74). Moreover, the complexity level of task solutions explained a significant proportion of the variance in item difficulty (*adj.* $R^2 = .48$). Overall, first evidence could be provided for pedagogical knowledge construct representation. Furthermore, teachers' situation-specific skills could be predicted by the complexity level. This result can be interpreted as further proof of validation of the TEDS-M instrument measuring pedagogical knowledge (for details, see Nehls et al. under review).

4.2 Profiles of Teachers

Profiles of teachers were examined in two analyses based on data of TEDS-Validate, which aimed to study the relation between various competence facets of teachers.

In the first study pedagogical knowledge was focused on in a specific analysis to investigate profiles of teachers. Starting from the assumption that qualitatively different profiles of teacher pedagogical knowledge exist, a Mixed-Rasch model was applied to identify such profile groups of teachers. For these analyses, a larger data base including several TEDS-M-studies was created: TEDS-Validate data

was merged with data from TEDS-FU and CME, which is another study on in-service teachers in Germany that applied the GPK test from TEDS-M (König 2015). Therefore, a total sample of 462 in-service teachers, mathematics and non-mathematics teachers was used, who had completed the GPK test. 35 teachers (8 %) had undergone training for teaching mathematics at primary school level, 343 (74 %) for mathematics at secondary school level, while 81 (18 %) had been trained for other subjects at secondary school level. The participants had an average teaching experience of about 11 years ranging from 0.5 to 41.0 years. Two kind of analyses were carried out, mixed Rasch models with increasing number of classes and a study of the resulting GPK profiles at item-level.

The profile analysis released two different groups: The two profiles differed in their overall test performance (quantitative differences in test scores), and they also showed differences related to the quality of responding to single items, which resulted in a variant ranking of difficulty in some items. These items were mainly related to the pedagogical task of dealing adaptively with student heterogeneity in the classroom. Teachers with qualification in mathematics outperformed non-mathematics teachers with regard to these items specifically.

Further validation analysis was carried out towards teacher beliefs (epistemological beliefs and beliefs of teaching and learning) and instructional quality those teacher groups provided to their students, confirming the higher competence level of the teacher profile group who was more successful in the GPK test (for details, see Nehls et al. 2020).

The second study focuses the relation between instructional quality implemented by mathematics teachers' and those competences. Although there exists quite a significant number of studies already, most studies have up to now been restricted to a limited set of constructs and variable-oriented approaches that assume sample homogeneity. As in TEDS-Validate teacher competence is conceptualised as a comprehensive multi-dimensional construct including subject-specific and generic facets regarding knowledge, skills and beliefs, these analyses followed a different approach. In contrast, the used person-oriented approach examined whether subgroups of teachers exist when teachers are assessed on a large set of competence facets. The analyses assessed mathematics teachers' subject-specific and generic knowledge, skills and beliefs applying latent profile analysis to this broad range of teacher measures. These profiles were then related to instructional quality implemented in terms of mathematics teaching. Based on data from TEDS-Instruct and TEDS-Validate four groups of mathematics teachers could be distinguished, who differed quantitatively and qualitatively. The first group of teachers with pronounced levels of knowledge and skills succeeded with respect to student support, cognitive activation and mathematics-related quality while they implemented a

medium level of classroom management. The second group of teachers with high levels of cognitive skills in professional noticing under a mathematics educational perspective (M_PID) and classroom management succeeded with respect to cognitive activation and mathematics-related quality despite only medium levels of knowledge. Classroom management was a strength of a third group of teachers characterized by medium levels of all competence facets. These teachers struggled with mathematics-related quality, cognitive activation and student support though. The fourth small group of teachers with rather low levels of knowledge and skills struggled with all facets on instructional quality (for details, see Blömeke et al. accepted).

4.3 Results Concerning Instructional Quality: Validation of the Instrument and Relations to Teachers' Competencies

A new instrument for the evaluation of instructional quality was developed within the framework of the TEDS-M research program based on live ratings of the instructional quality classroom teaching. Based on data of TEDS-Validate and TEDS-Instruct the three basic dimensions of instructional quality (classroom management, student support and cognitive activation) and a content-specific dimension referring to mathematics-educational aspects (e.g. use of representations, explanations and examples) were measured (Jentsch et al. under review). Moderate correlations between teachers' professional noticing and domain-specific dimensions of instructional quality could be identified, but only weak correlations between PCK and subject-related quality of instruction were observed (Schlesinger et al. 2018). Overall analyses on the impact of teacher competencies on instructional quality and students' learning gains are currently in progress (König et al. under review).

To validate the instrument on teaching quality used for class observation, a supplementary project to TEDS-Validate, the TEDS-Video study, was carried out in which 15 teachers of the TEDS-Instruct study from Hamburg were subjected to renewed class observation and these lessons were simultaneously videographed. The sample consisted of 8 (53 %) females, grades in first and second teacher examination were 1.8 and 2.0, and the average age was 36 years ranging from 28 to 71. The professional experience averaged to 6 years ranging from 0.5 to 30 years. A comparison of the methods between live rating directly in the classroom and video rating from the videographed lesson was made possible by a subsequent rating of these videos after live rating had taken place by different raters. The results available so far indicate that mode effects only occur in some dimensions of

teaching quality due to the two types of rating. Video rating yielded slightly higher rank orders in classroom management than live rating ($z = -2.67, p < .01$, two-sided Wilcoxon test). We also found that student support was rated more reliable through video analyses (*rho* = .20 vs. *rho* = .65), whereas cognitive activation received better psychometric results during live rating (*rho* = .73 vs. *rho* = .51) (Cronbach et al. 1972). There was no meaningful difference between modes for the content-specific dimensions. Since the videographies also offer the possibility to analyse the lessons qualitatively, analyses on interaction patterns in the lessons are planned, especially on how teachers deal with student errors in their lessons (Benecke 2018).

4.4 Instructional Quality Measured via Task Quality

In the COACTIV study, instructional quality was measured via the quality of the mathematical tasks used by the teachers. Additional analyses refer to this approach and further develop the classification system of task quality based on a rational task analysis (Jordan et al. 2006). This classification system is currently applied to analyse the quality of the tasks used by 31 teachers from TEDS-Validate, who took part in the classroom observation study on instructional quality. Altogether 2600 mathematical tasks, i.e. between 25 and 197 tasks per teacher (two lessons of 90 minutes) form the data base and are analysed according to content-related and procedural competencies, cognitive and linguistic complexity and special task characteristics. The analyses aim to examine the central assumption that there is a strong correlation between instructional quality measured via classroom observations and task quality (for the first results, see Ross and Kaiser 2018).

4.5 Comparative Study between East and West

In a complementary study – the study TEDS-East-West – the question was examined how far theoretical frameworks, conceptualisations and instruments on teacher competencies developed in a Western context can be transferred to an East Asian context using China and Germany as paradigmatic examples of East and West. Analyses pointed out major similarities of the two contexts within in the conceptualization of teacher competence as a multidimensional construct comprising knowledge, situation-specific sub-competencies, and beliefs concerning the teaching and learning of mathematics. Distinct differences could be identified with the Chinese frameworks putting more teaching-related competencies in the foreground.

Extensive adaptation and validation studies were carried out using data from TEDS-Instruct (118 teachers) and newly sampled data in China (203 teachers). A comparative analysis of teacher competence frameworks developed in Eastern (Chinese) and Western (German) contexts pointed out major similarities of the two contexts, for example the conceptualization of teacher competence as a multi-dimensional construct comprising knowledge, teaching-related skills, and beliefs. Distinct differences could be identified as well, with the Chinese frameworks emphasizing more teaching-related competencies than the Western (German) frameworks Based on a qualitative approach on examining validity of the framework and the instruments used, namely elemental validity and a quantitative approach, namely construct validity to validate the framework, the results of both approaches suggest satisfactory validity for the adaptation. Overall, the results pointed out that the examined teacher competence framework and its instruments can be used for comparative analyses in both countries (Yang et al. 2018).

Further comparative analyses on teachers professional noticing, i.e. perception, interpretation, and decision-making competencies, which was evaluated video-based, pointed out that German teachers showed significantly better achievements than Chinese teachers on noticing aspects related to general pedagogy. Chinese teachers performed more strongly than their German counterparts on noticing aspects connected to mathematics instruction. Further analysis found that German mathematics teachers showed particular strengths in the sub-facet perception of noticing, whereas Chinese teachers tended to be strong in the sub-facet 'analysing and decision making' of central classroom incidents. These results pointed out that societal and cultural factors, such as different philosophical paradigms, traditions of teacher education, and teaching and mathematics curriculum traditions are influencing strongly teachers' professional noticing (Yang et al. 2019).

4.6 Summary

Coming back to our first research question, how far can we provide empirical evidence that the measurement instruments developed within the TEDS-M research program have predictive validity for teaching mathematics at high quality, we could show that especially the content-related knowledge parts of teachers competence together with noticing as situation-specific competence facets influence the instructional quality of their lessons. Especially the identification of different teacher profiles explained the relation between the knowledge part of teacher competence and the situation-specific skills with instructional quality under a content-related and a pedagogical perspective (e.g. related with adaptivity).

Concerning the second research question of the added value of the video-based measured situation-specific competence facets our study reveals lower correlations between teachers' professional noticing and domain-specific dimensions of instructional quality as expected. Especially the comparative study between Chinese and German in-service teachers showed culture-specific strengths and weaknesses of both teacher groups.

5 Outlook

Central lessons learned from the TEDS-M research program and specifically TEDS-Validate are as follow: We consider to highlight the empirical validation of the multidimensionality of teacher competence and, therefore, derive the need for evaluating teacher competences with different assessment methods focusing on different sub-facets of teacher competence. Especially professional noticing consisting of the situated competence facets play an important role for providing instructional quality from a general pedagogical perspective as well as from a content-related perspective. Thereby, these situated competence facets have the potential to integrate subject-based professional knowledge with general pedagogical professional knowledge via teaching incidents and classroom activities. The central lesson learned leads to the following research focus in the coming transfer phase of TEDS-Validate.

Initial teacher education requires elaborated and carefully designed school-based practical opportunities to learn – often related to as various types of school-based practicum. These learning opportunities intend to enable pre-service teachers to relate their professional knowledge gained during the academic part of teacher education with practical teaching situations and the associated situation-specific requirements. The application of theoretical knowledge in practical situations, for example the implementation of teaching plans and the handling of students' reactions in specific learning situations, are general objectives of practical phases of teacher education. However, the extent to which professional teaching skills can be promoted in such practical phases during university studies is still a largely open question. In their survey of the state of research in the German-speaking discussion, König et al. (2018) noted a clear lack of empirical studies that could prove the effects of extended practice in initial teacher education. An international review also concluded that the state of research on the effectiveness of extended practicum phases in teacher education can be described as very narrow (Lawson et al. 2015).

To address this research gap the planned and already approved transfer study of TEDS-Validate will transfer the conceptualizations and evaluation instruments

from TEDS-Validate into the practicum phase within the master studies of initial teacher education. The video-based tests for professional noticing including perception, interpretation and decision-making developed for in-service mathematics teachers and validated in the current project will be used with samples of pre-service teachers in the master phase of six German universities from several federal states. As the project partners will benefit through their involvement and support of data collection and developing a shared understanding of findings, these planned transfer activities can therefore be expected to provide a clear added value in terms of dissemination of the instruments developed and the use of the findings gained with the help of these instruments for the future design of practical learning opportunities in the field of initial teacher education. Moreover, the transfer of major insights into teacher competence as provided by TEDS-Validate into higher education will clearly contribute to important discussions on reforming teacher education such as the ongoing debate about an adequate ratio of theory and practice or about making concrete what kind of competencies pre-service teachers should elaborate on during their professionalization process and career development.

To sum up, the TEDS-M research program provides a broad overview on the evaluation of initial teacher education and professional development of teachers, its efficiency and necessity for further developments.

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