VIDEO-BASED MEASUREMENT OF PRIMARY MATHEMATICS TEACHERS' ACTION-RELATED COMPETENCES

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Teacher cognition is seen as an important factor for the quality of instruction and, accordingly, student learning of a subject. However, in-depth research on these relations can only be done if a sound theoretical model for subject-specific teacher cognition (knowledge and competence/practical skills) and corresponding measures are available. This work aims at the development of reliable and valid measures for primary school teachers in mathematics. The subject-specific cognition is modeled as basic professional knowledge (BK) and further two components of reflective competence (RC) and action-related competence (AC). Using video-based items, we developed a computer-based standardized test and collected data of N = 85 primary mathematics teachers. We present results on the quality of the measures and have a closer look on the structure of teacher cognition.

MEASURING TEACHER KNOWLEDGE

Despite the broad consensus of the importance of teachers' subject-specific cognition for the instructional quality of lessons and the learning of students, concepts to model these cognitive structures are still deficient. As a consequence, research is still narrow and focuses on single aspects of teacher cognition (Kunter, & Klusmann, 2010). For example, the facets of mathematics teachers professional *knowledge* has been elaborately described based on Shulman's (1986) topology and measures for mathematics teachers' *content knowledge* (CK) and *pedagogical content knowledge* (PCK) were developed successfully (e.g. COACTIV for secondary teachers in Germany, Baumert et al., 2010; MKT for elementary teachers in the US, Hill et al., 2004; TEDS-M for pre-service teachers in various countries, Döhrmann, & Blömeke, 2012). Some studies provided evidence that teacher knowledge is positively related to instructional quality and student learning (Baumert et al., 2010; Hill et al., 2007).

These results strengthen the assumption that subject-specific professional knowledge of teachers guides their instructional actions (see also Hattie, 2009). It is consensus that teacher knowledge is highly specialized, context-bound, and needs to be flexible in order to cope successfully with emerging classroom situations. But so far there is little specific evidence how teachers use their subject-specific knowledge to create and conduct instruction. Moreover, the relationship between teacher knowledge and the ability to use this knowledge in and for action is considered as complex and divergent. Particularly, this divergence can be described by the two commonly known phenomena of *inert knowledge* and *tacit knowledge*: Knowledge can be inert, so that a teacher might perform a knowledge test well, but is not able to utilize this knowledge

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in classroom situations. Contrary, if teachers hold tacit knowledge, they react well during classroom situations, but are not able to make this practical knowledge explicit in a knowledge test (Lindmeier, 2011).

To address these issues, alternative approaches have been developed in order to investigate facets of teachers' cognition "beyond" knowledge: Research is then focused on usable teacher knowledge (e.g. Kersting et al., 2012), on professional vision as knowledge-based process (e.g. Stürmer et al., 2013; Vondrová, & Žalská, 2013) or on constructs of competence (our approach, see below). All of these approaches account for the importance of the applicability of teacher knowledge and, hence, seek for valid methods to tests the applicability in standardized procedures. As video-vignettes are seen as a possibility to convey the typical demands of teaching, all these approaches make use of them. However, the ways of using the video-vignettes differ and are very specific for each approach (see Lindmeier, 2013).

TEACHERS' SUBJECT-SPECIFIC COMPETENCE

Our approach accounts for the variety of cognitive demands of typical tasks of teaching and considers knowledge, skills, and abilities needed to master these demands. In a European tradition, we use the concept of competence to model these complex ability constructs (Koeppen et al., 2008). Therefore, we understand subject-specific teacher competences as learnable, highly context-specific, individual cognitive dispositions that are required to master the typical demands of teaching a subject, in our case mathematics. In general, there are two groups of typical teacher tasks that clearly differ in their cognitive demands: (1) Tasks that occur during preparation and post-processing of instruction and are coined by reflective demands, e.g. choosing an appropriate representation and/or correcting students work, and (2) tasks that are related to the instruction itself and characterized by the spontaneous, immediate, interactive, and concurrent demands of teaching. Accordingly, Lindmeier (2011) suggest a subject-specific model for teacher cognition with three components: A *basic knowledge* (BK) component comprising teacher knowledge (CK and PCK). Two complementary components of competences are conceptualized as *reflective competences* (RC), and *action-related competences* (AC). The RC holds abilities and skills required for pre- and post-instructional tasks, whereas the AC comprises the abilities needed to fulfill the demands during instruction. Thus, for both components, basic knowledge is seen as a prerequisite that has to be enacted in situations related to teaching mathematics. However, the way of using this knowledge differs, as aims, situations, and retrieval modes differ between out- and in-classroom teacher work.

In a feasibility study with video-based measures, the components could be separated empirically for secondary in-service (N = 28) and prospective (N = 22) teachers (Lindmeier, 2011). A replication with a larger sample has to follow. In the present study, we followed the approach to model the subject-specific cognition of primary mathematics teachers.

Primary school teachers in Germany

Primary school teachers in Germany teach up to grade 4 and are specialized in one or two subjects. Typically, the children are taught mainly by a class teacher, which implies that mathematic is also taught by teachers without formal education for this subject. For Germany, Richter et al. (2012) report that up to 48% of primary teachers teach mathematics as not-certified teachers in some federal states. Clearly, German pre-service teachers that are educated as "primary generalists" exhibit a significantly lower content-specific knowledge than pre-service teachers that are "primary mathematics specialists" (Senk et al., 2013). It is assumed that this lack of subject-specific knowledge affects the quality of instruction and, hence, student lear¬ning. However, the findings are inconsistent for this assumption (for Germany: Richter et al., 2012; Tiedemann, & Billmann-Mahecha, 2007; for an international overview: Hattie, 2009). In addition, these findings rely usually on measures of teacher knowledge (at best, or even only on information about certification) and do not account for possible differences of teacher abilities to use this knowledge in and for instruction, as apt measures are still missing.

Competence structure

If teacher competences "beyond" knowledge can be measured, the relation between knowledge and competences could be investigated. This can be used to describe different profiles of teacher cognition, to identify favorable profiles, and thus lay ground for evidence-based specific professional development programs, e.g. for not-certified teachers. As mentioned above, we assume that the BK is a prerequisite for the two competence components. For the interaction between RC and AC two assumptions can be derived theoretically: On the one hand, considerations that account for the instruction-related knowledge as highly-specialized craft knowledge that is in addition strictly situated in practice (Leinhardt, & Greeno, 1986) may lead to the hypothesis that AC and RC do not show any relation beyond their common rooting in BK ("independent AC/RC hypothesis"). On the other hand, other views on the work of a teacher as reflective practitioner (Schön, 1990) would lead to the expectation that RC plays a mediating role between knowledge and AC ("mediating RC hypothesis"). Lindmeier (2011) found indications for the independency of RC and AC for secondary teachers.

RESEARCH QUESTIONS

The aim of our study was to adapt the three-component model of teacher cognition for primary mathematics teachers and develop standardized measures for individual diagnosis of the components in order to allow for a structural investigation of teacher cognition. Therefore, we worked on the following research question: (1) Is it feasible to develop valid and reliable instruments to assess the subject-specific components of primary teachers as BK, RC, and AC? (2) Which relations will prevail between the assessed competences? In particular, how are the relations between BK, RC, and AC?

METHODS

Sample

Overall, N = 85 teachers participated in our studies. All participants of this convenience sample teach mathematics at primary schools in Schleswig-Holstein (a federal state of Germany). The age of the teachers ranges between 25 and 63 years (M = 45.3). The majority of the participants were female (89.4%) and nearly half of the sample (51.8%) was certified in mathematics.

Instruments

For adequate competence measures, items have to reflect appropriately the context-specific demands that were used to conceptualize the competence (Koeppen at al., 2008). Overall, we realized our measures as standardized, computer-based tests. We used the software vKID (Lindmeier, 2011), where a variety of item types can be realized. Specifically, we tailored the items to mirror the characterizing demands of the three components BK, RC, and AC. As mentioned before, items based on video-vignettes are considered as especially suited to convey the demands of teaching, as they account for the complexity of instructional situations. Moreover, recent studies illustrated that video-based items are indeed appropriate to elicit teacher abilities that go “beyond” teacher knowledge (see above).

Hence, for the *AC* measure, we developed short video-vignettes of typical classroom situations from primary mathematics instruction. Since AC is especially characterized by its spontaneous and immediate demands, we used a direct oral answer format. Teachers had to answer under time pressure and their reactions were audio recorded. Due to the spontaneous oral answers, this item type differs from other video-based approaches and has been already successfully implemented by Lindmeier (2011). AC was measured with 8 items by two types of video-based item: Some items were focused on the teachers’ abilities to address “students’ cognition” and teachers had to cope with a student’s individual strategies and misconceptions. The other items focused on abilities to deal with “representations and explanations” in instruction. The *RC* (9 items) was captured by picture- or video-based items and the teachers’ answers were partly direct and audio recorded, partly written. According to the conceptualization of RC, the teachers were instructed to act as they were in a post- or pre-lesson period. They were allowed to have sufficient time for reflection. We used two different types of items within the RC measure: First, the item type “students’ cognition” focused on the evaluation of student work, so that e. g. the rationale of a systematical error had to be analyzed. Second, the item type “representation and explanation” focused on planning snippets of lessons that can be related to a given video-vignette. Finally, the *BK* (9 items) was assessed with items comparable to the items from other studies with focus on teacher knowledge (see above, Döhrmann, & Blömeke, 2012, Hill et al., 2004). However, we presented the items via computer, so that the teachers answered written items by typing their answer. The items were constructed to mirror content knowledge as well as pedagogical content knowledge.

However, we do not differentiate these in our analyses. We restricted the content for the whole test to arithmetical topics such as numbers, the place-value system, arithmetical strategies, and operations. The teachers completed the test individually at their own pace (they needed 42-88 min, M = 68 min to answer the test). In the beginning, a technical introduction with sample items was given to avoid technical issues with the handling of the computer. Furthermore, information on background variables was collected, including information on variables to assess criterion-irrelevant difficulties depending on the computer usage.

All audiotaped answers were transcribed before two trained persons coded them independently with a detailed manual. The codes were based on findings from pri¬mary mathematics education and accounted for aspects of high-quality instruction. The inter-rater reliability was moderate to high with a range of Cohen's Kappa of κ = .74-.94. The rate of missing data due to skipped items (time-on-task < 2 sec), skipped videos or technical problems was low (2.0%). We handled the missing information in background variables by case-wise deletion. Missing data in knowledge and competence measures is accounted for by using individual mean values of the answered items per scale (relative solution rates). Further, we used a cut-off value, so that scores were only computed if at least 75% of the data per scale was available. The missing data technique we used is discussed, as the resulting bias was not systematically assessed so far. However, if the rate of missing data is low and the mean item solution rates for items with missing data and without is comparable, it is seen as not problematic (Enders, 2010).

RESULTS

Feasibility: Reliability and Validity

For evaluating the feasibility of measuring the three proposed scales, we assessed the reliability in terms of internal consistence (Cronbach's Alpha) and compared it to the overall scale. The results of the analyses are reported in Table 1.

Scale	Cronbach's Alpha (Precision)	Est. Cronbach's Alpha[1] for scale length 11	Solution Rates (SD)
BK (7 items)	.68 (.03)	.77	.55(.12)
RC (7 items)	.64 (.04)	.73	.49(.20)
AC (8 items)	.69 (.02)	.76	.38 (.15)
Overall scale (22 items)	.83 (.01)	.70	.47(.17)

[1]Spearman-Brown prediction formula.

Table 1: Cronbach`s Alphas and estimated Cronbach`s Alphas for scale size 11

The BK and RC scale had to be reduced by two items each, due to obvious item misfit or/and extreme item difficulties. The reliabilities of the intended scales are sufficient considering the heterogeneous item types. Furthermore, the estimated Cronbach's Alphas for the BK, RC, and AC scale show slightly higher internal consistencies than the overall scale. Thus, the three scales could be used as intended.

In order to evaluate the criterion validity, the *mathematics certified teachers* are compared with the *not-mathematics-certified teachers*. Table 2 shows the results of a t-test between the groups. The mean differences for BK, RC, and the overall scale are of medium to high effect size. But for AC, no statistically significant difference between the groups was found.

Scale	Certified Teachers N = 43	Not-certified Teachers N = 41	t(82)	Effect Size Cohen's d
BK	64.63	46.62	3.91**	.87
RC	55.58	41.68	2.82*	.62
AC	37.39	37.39	0.00 n.s.	.00
Overall scale	52.10	41.69	2.86*	.63

Table 2: T-Test for group differences between math-certified and not-math-certified teachers (* $p < .01$, ** $p < .001$)

Competence Structure: Relations between the three components

Correlations were used to assess the relations between BK, RC, and AC. We found BK significantly related to RC ($r(84) = .53$, $p < .01$) and AC ($r(84) = .26$, $p < .05$). Moreover, the relation between RC and AC is statistically significant ($r(84) = .40$, $p < .01$). In order to evaluate in detail the relationship between RC and AC, partial correlation (controlling BK) was calculated. Controlling for BK, the partial correlation of RC and AC remains $r = .32$ ($p < .01$). Hence, we rejected the "independent RC/AC –hypothesis" and assessed the "mediating RC-hypothesis". As mentioned above, significant correlations exist between BK and RC and between RC and AC. A hierarchical linear regression showed that the original effect ($ß = .26$, $p < .05$) of the BK on AC decreased ($ß = .07$ n.s.), when RC was entered as a control variable. Sobel's test confirms that the decrease of the effect was significant ($t = 2.71$, $p < .01$). Hence, we find evidence for a mediator model, with RC mediating the relation between BK and AC. Using RC and BK as a predictor, 17% of the variance of the AC-scores could be explained.

DISCUSSION

The aim of this study was to develop competence measures for primary mathematics teachers' cognition based on the proposed model. The empirical results of the reliability analyses indicate that the three components of subject-specific teacher cognition could be operationalized in distinct measures. The scales were seen as coherent enough, despite the inhomogeneous item types, item formats, and content areas. Consequently, the results of Lindmeier (2011) could be transferred to the context of primary teachers. Further, the measures are examined with the aid of the different groups, namely teachers certified and not-certified in mathematics. The instrument is able to indicate the expected differences and a mean difference for BK, RC, and the overall competence is observed. Surprisingly, no difference could be observed for the scale of AC. One explanation could be the nature of the video-presented classroom situations: We decided to use very prototypical situations that are expected to appear in every primary mathematics classroom, so that teachers who regularly teach mathematics could have learned to deal with these situations. But this consideration would lead to a limiting point of our study in respect to the predictive validity of our measures for instructional quality: If a teacher reacts appropriately in a very typical situation that is clearly focused in our vignette, it remains unclear whether the teacher would also "see" this situation during lesson (see above, professional vision). Consequently, future research has to show how far the measures are valid for predicting classroom performance and student achievement.

Our analyses of the relations between the measures showed that the relations between BK and AC and between AC and RC are of medium size, between BK and RC even large. Hence, the scales for RC und AC capture facets of teacher cognition that go "beyond" knowledge in the sense that the scales depend on professional knowledge but mirror further abilities to use knowledge in typical teaching tasks. Especially, for the AC that was measured by video-based items, these findings are in line with the studies that follow related ideas to measure the applicability of teacher knowledge.

The relationship between RC and AC is of medium size even when controlling for BK. Consequently, in this study, we do find a stable relation between RC and AC for primary teachers, what differs from our findings for secondary teachers. Further analysis shows that RC mediates the relationship between BK and AC, but this mediation explains only a small part of the variance in AC. This can be interpreted as follows: Although AC depends on BK and RC, AC clearly differs from BK and RC. We would explain this difference with the underlying different cognitive demands. Altogether, our findings underpin the important role of teacher knowledge. But at the same time we can elicit teaching-related competences that go beyond knowledge and thus would conclude that basic knowledge might be not sufficient to describe the variance of subject-specific teacher cognition.

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