WHAT DO MATHEMATICS PRE-SERVICE TEACHERS LACK FOR MASTERING INSTRUCTIONAL DEMANDS?

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In addition to subject-specific professional knowledge, research in teacher education recently focusses on teachers' abilities to master subject-specific instructional demands. Although knowledge is seen as a prerequisite for according competences with close relation to instructional demands, the complex relationship between knowledge and according competences is not understood in detail. In order to investigate this relationship, we analysed answers to video-based instructional situations of 4 mathematics pre-service teachers. The case study illustrates that despite of sufficient teacher knowledge and perception abilities, the ability to give helpful feedback in instructional situations can be lacking. Our cases give indications, what factors might further the area of research.

RESEARCH IN TEACHER COGNITION

Subject-specific knowledge

Research in teacher education brought up a variety of models for teacher competences (e.g. Hill, Schilling, & Ball, 2004; Kunter et al., 2013). In this research, there is a tendency of narrowing teachers' cognition to declarative knowledge. Especially when it comes to subject-specific knowledge, research often focusses on teachers' content knowledge (CK) and pedagogical content knowledge (PCK). Those constructs have been successfully described, conceptualized, and operationalized in many studies so far (e.g. Shulman, 1986; Kunter et al., 2013; Hill et al., 2004). Despite some conclusive evidence that mathematics-specific knowledge is a predictor for instructional quality and student learning (e.g. Kunter et al., 2013), recent discussions pointed out limitations. In particular, it is questioned if standardized measures for teacher knowledge are sufficient to predict teachers' abilities to use this knowledge in the classroom (e.g. Blömeke, Busse, Kaiser, König, & Suhl, 2016; Knievel, Lindmeier, & Heinze, 2015). Given this issue, recent studies brought up alternative approaches of modelling and assessing teachers' subject-specific skills and abilities which are beyond declarative knowledge and complement previous research.

Subject-specific action-related competence

There are currently different approaches on expanding classical models of teacher knowledge. For the present research, we use the model of Lindmeier (2011). In this model, the understanding of subject-specific competences considers the variety of typical demands that come along with teaching a subject and, in a European tradition,

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defines competence as the ability to master those demands. Consequently, the model defines the ability to master "core teacher tasks" (Lindmeier, 2011, p. 108) of instructional processes as action-related competence (AC) which are characterized by spontaneous, immediate, and interactive demands (Knievel et al., 2015).

AC comes into play when teachers e.g. have to react to a conceptual misconception displayed through a student's statement during classroom discourse or have to give immediate feedback to a student's mathematical question. However, separating action-related competence from teacher knowledge from a theoretical perspective leads to the need to investigate how knowledge and competence relate to each other. It can be assumed that AC covers PCK and CK as necessary components supplemented by the ability to apply or enact this knowledge (Lindmeier, 2011). Hence, teacher knowledge is not found sufficient to master demands of actual teaching. With this study, we want to investigate which skills might be suited to disentangle the complex relation between a profound knowledge and high-quality actions.

PREREQUISITES FOR ACTION-RELATED COMPETENCE

Describing skills and abilities that are necessary for teaching on a conceptual level has relevance not only for research in teacher education but also for teacher education at university. There is evidence from the TEDS-M study indicating that characteristic differences of teacher education programmes between countries result in characteristic differences in pre-service teachers' knowledge (Wang & Tang, 2013). Evidence for the initial acquisition of action-related competence during teacher education is missing so far. Understanding the conditions that lead to teacher competence might help to improve programmes for mathematics teachers at university. In the following, we delineate individual factors that may have an effect on action-related competence.

As AC is conceptualized based on demands that typically occur during mathematics instruction, a closer look at prototypical processes of teacher action in instruction gives indications for possible influencing factors. They can be described as traits that are necessary for three steps usually modelled for such processes (e.g. Blömeke et al., 2016): 1) perceiving a situation in teaching and see what is essential e.g. paying attention to a student's production in class despite of competing attentional distractions in the complex teaching situations, 2) interpreting and making sense of the perceived, e.g. in order to identify a misconception, and 3) reacting adequately to the situation, e.g. through offering an apt hint that may turn the student's misconception into a mathematical learning opportunity. Since the demands are considered to be subject-specific, it can be assumed that teacher knowledge (CK and PCK) is needed to master these demands.

Focusing on the first steps, research on professional noticing skills may be helpful to delineate cognitive dispositions necessary at the stage of perception. For example, mathematics teachers' noticing has been described as the ability to attend (step 1) and then use existing knowledge to interpret events (step 2) that are mathematics-specific (e.g. Sherin, Russ, & Colestock, 2011). Although noticing could therefore be useful for investigating mathematics action-related competences, the need of subject-specific knowledge makes it difficult to separate perception skills from knowledge when it comes to operationalization. Another approach is followed by Miller (2011). Teachers' basic abilities to 'perceive important features in a given classroom situation' are described as teachers' situation awareness (SA) (p. 51). SA is seen as a function of general cognitive abilities which allow teachers to quickly realize simultaneous events in a situation (e.g., student 1 talks to student 2, student 3 raises his hand, student 4 is doing something under her desk). The concept of situation awareness therefore might be useful to describe teachers' perception skills for 'prototypical' instructional situations that are, to a certain extent, independent from subject-specific knowledge. However, neither the concept of situation awareness nor another fundamental perception skill has recently been investigated empirically with respect to its relation to teacher competences. Regarding the third step, skills like decision-making were suggested as influencing factors, but research on teachers is still emerging in this field.

To sum up, it is currently an open question on which traits other than subject-specific knowledge mathematics teachers' AC is based. From a theoretical perspective, situation awareness – in instructional processes – is a subject-unspecific construct which, together with subject-specific knowledge, contributes to AC.

RESEARCH QUESTIONS

Considering the need of research pointed out in the previous section, we considered the following research questions: *Is situation awareness (SA), in addition to mathematics-specific knowledge (CK, PCK), influencing action-related competences (AC) of pre-service teachers? Is there evidence for further factors contributing to action-related competence (AC)?*

METHODS

In order to investigate our research question, we administered tests for the constructs in question to a group of mathematics pre-service teachers of Kiel University (quantitative survey). On the basis of the test performance we then selected specific cases in order to investigate and identify factors influencing AC.

Instruments

This section reports on the instruments used for the quantitative survey as far as possible within the limits, as it is necessary to access the case study reported below. Mathematics AC was measured by a video-based instrument (extension of Lindmeier, 2011). Each of the 8 items contains a short video-vignette of a classroom situation typical for secondary mathematics instruction. The situations focused on problems in algebra (5 items) and calculus (3 items). Depending on the item type, the response should be e.g. an explanation that solves a students' mathematical question or an adaptive feedback that helps students with a mathematical problem without giving the solution. Since AC is characterized by its spontaneous and immediate demands, AC items had to be answered in a microphone with an oral statement under time pressure. A specialized software was used for the computer based implementation (see Lindmeier, 2011, Knievel et al., 2015 for a details on AC operationalization).The resulting audio recordings were coded and scored by three trained persons independently under usage of a detailed a-priori developed manual. Partial scores were applied (score 2: adequate; score 1: partially adequate, score 0: inadequate answer). The responses were considered adequate if they comply with the following aspects of high quality teaching (cf. Knievel et al., 2015): correctness of content, building on students' thinking, and clarity and appropriateness of explanation/stimulus without giving irrelevant information. First results for interrater reliability were acceptable with a range of $\kappa = .65–.89$ (Fleiss' Kappa).

Items for assessing mathematics PCK and (school-related) CK have been developed for pre-service teachers in previous studies (e.g. Loch, Lindmeier, & Heinze, 2015). For the present study, we used their empirical results to select items and assemble the instruments (PCK: 12; CK: 7 items). All items were in a constructed response format.

Situation awareness was conceptualized as a subject-unspecific ability of teachers to perceive critical incidents. In particular, our conceptualization of situation awareness focusses on classroom management issues and situations that typically occur in class (e.g. noticeable or inappropriate student behaviour). We developed an 8-item instrument using material of other-than mathematical instruction of a German video study (Seidel, Prenzel, & Kobarg, 2005). For each item, a short video clip is to be watched once. After that, a constructed-response question shows up offering (true and false) details of the situation in the video-clip (Figure 1).

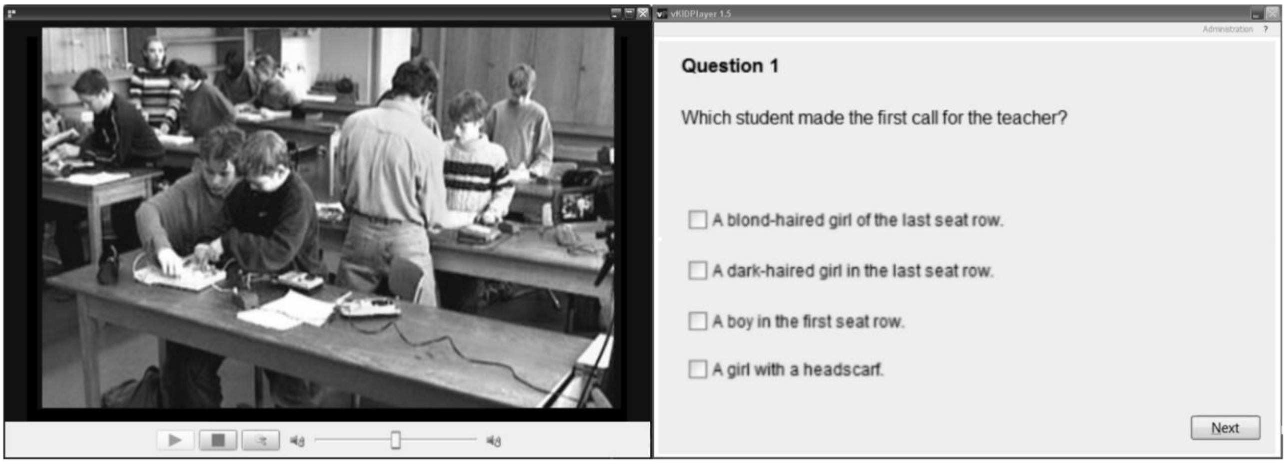

Figure 1: Item for situation awareness (left: video clip; right: single-choice question).

Case selection

The survey was conducted with pre-service teachers enrolled for the mathematics teacher programme for upper secondary level at Kiel University (Germany). For our analysis, we selected a sample of 4 cases (3 females, mean age 25.3 years) out of 41 according to the following criteria: Person shows high scores in CK, PCK and SA, but low scores in AC. Five participants reached the criterion for CK, PCK and SA, with only four of them having low AC-scores below the average. Theoretically speaking, those four participants should have good pre-requisites for achieving high scores in AC, but were not able to achieve expected scores. Overall, the AC data of this sample contains 26 responses, 4 empty responses, and 2 missing due to test abortion. Hence, analysing those responses might give evidence why knowledge and perception skills do not suffice for the mastery of teaching demands.

RESULTS

In order to get an insight why the selected participants showed a poor performance in AC, we reviewed the oral answers in the video-based test with the aim of describing why these were not adequate. For that, we analysed whether answers rated as not-adequate in the survey (score 0 and 1) can be characterized in categories that e.g. describe problems in perceiving, interpreting or reacting to the given situation.

We found that the 26 answers can be characterized using only four categories: (1) answers that are not useful at all, e.g. statements that do not contain an explanation although it was expected, (2) answers that lack correctness of content, e.g. suggestions that are mathematically wrong, (3) answers that are partially adequate but contain supplements that are irrelevant or irritating, and (4) answers that are considered not helpful for the students, although the students' problem and the problem solution is (probably) understood by the participant, e.g. explanations that are targeted at an intellectual level far beyond the skills of the student/grade level or hints that trigger a strategy that is likely to hinder the conversion of a situation into an opportunity to learn. None of the 26 answers explicitly showed a misunderstanding of the situations that might occur due to the fact that the situations had to be answered spontaneously and under time-pressure. That gives evidence that the participants did indeed not lack perception skills, what can be seen as validity evidence for the measure of SA.

The deficit that occurred – by far – most often is characterized by category 4. The participants seemed to know what the student's problem is (which indicates sufficient content/pedagogical content knowledge in line with the case selection criteria), but were not able to phrase an answer that is helpful for the student:

Situation (Item 1): 6^{th} grade, topic: total order of fractions. Three students are working on a mathematical task. The teacher asks them, if they have finished and what exactly their task was. The students reply that they had to find five fractions between 3/8 and 7/8, but that they have found only the three fractions 4/8, 5/8 and 6/8.

Participant 2: There are more fractions than just eighth. There are also half and quarters. Maybe you can find more fractions with this hint.

In item 1, it was asked to give a helpful stimulus so that the students may find the correct solution on their own. Participant 2 correctly focussed on different representations of the fractions. That indicates that participant 2 understood the mathematical problem and the problem of students' thinking. Possibly, the participant even knew the right strategy to solve the mathematical task herself. However, the participant prompted a strategy that might infer negatively with finding more fractions as it lacks coherence with the presented situation. Therefore, this answer is considered to be not adequate and was characterized with category 4. Overall, we found 14 other responses that comparably lack instructional coherence.

Besides that, we found 5 statements that are partially adequate, but contain further information that is irrelevant and not helpful or, even worse, irritating:

Situation (Item 3): 6th grade, topic: division of fractions. Two students were asked to present their results on the board. The first student, Simon, multiplies 4 x 3/5 using (4x3)/5. The second student, Mailin, divides 2 by 2/3 using (2:2)/3.

Participant 3: Mailin, we already discussed that multiplying and dividing fractions work differently. Do you remember the reciprocal rule of division? (…) What does division mean? What does multiplication mean? Multiplication means that we get a part of something (…) and dividing means that we divide something, e.g. to people. (…) You have to turn the second fraction upside down (…). And then, you can go on just like Simon did.

For item 3, it was asked to give a solution and an explanation for Mailin's problem. Participant 3 gave the correct solution and an adequate explanation using the reciprocal rule of division. However the participant added several phrases that do not help to solve this particular problem, in contrast, might irritate as the expressed conceptions for multiplication and division are not fitting to the problems presented.

Participant	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8
1	4	3, 4	3	3, 4	4	1	4	4
2	4	3, 4	4	2	1	2	4	4
3	*correct*	2	3	1	*correct*	4	4	*missing*
4	1	1	4	4	*correct*	*correct*	2	*missing*

Table 1: Classification of the answers to AC items of the selected participants
(1: no useful answer, 2: lacking correctness of content, 3: irrelevant/irritating supplements, 4: feedback not helpful)

Given the characterization of all analysed answers (Table 1), some tendencies are visible regarding the participants' action under time pressure. Participant 1 showed sufficient knowledge for perceiving and interpreting the situations but deficits in providing precise and helpful teacher actions in almost every item. Participant 2 most often showed deficits in mathematical correctness, giving evidence for lacking CK. She additionally showed deficits in providing helpful feedback twice, although the required knowledge seemed to be present. Participant 3 showed multiple deficits in CK, although this case only contained a smaller number of answers that were rated non-adequate. Participant 4 skipped two items after watching the video, which could indicate problems with understanding the situation (lacking SA, CK or PCK) or missing strategies for responding to the situation (lacking PCK).

DISCUSSION AND IMPLICATIONS

The main aim of the present study was to explore factors that may contribute to pre-service mathematics teachers' action-related competence, i.e. teachers' ability to react adequately in a classroom situation under time pressure. We selected specific participants from a quantitative survey with high knowledge (CK, PCK) and situation awareness (SA). The results indicate that the low AC of the selected participants is often not simply a lack of knowledge or situation awareness. More than half of the answers did not show an adequate or helpful teacher action for the given situations, although the participants seemed to be aware of the students' problem and the problem solution. Some of the remaining answers contained adequate approaches but turned out to be only partially adequate due to irrelevant or inappropriate supplements. Again, this gives evidence that the difficulties rather resulted from difficulties in responding than understanding a problematic situation.

Based on these results we conclude that the pre-service teachers were able to apply their CK, PCK and SA to understand the challenges in the classroom situations even under time pressure. In the terms of Sherin, Russ, and Colestock (2011), the participants noticing skills were sufficient. However, they showed a weak performance when they had to use their CK and PCK for an adequate subsequent teacher action. The latter might be caused by two different reasons. First, we see (indication of category 3) that the quality of knowledge may be a factor to be considered in more detail. Instruments in teacher knowledge usually focus on declarative knowledge, therefore, measures of teacher knowledge may not reflect the usability of this knowledge for specific situations. Recent research shows how PCK can be differentiated in the types of declarative, propositional and episodic case knowledge with expected different characteristics with respect to usability (e.g. Kuhn, Alonzo, & Zlatkin-Troitschanskaia, 2016). Future approaches may hence seek to assess also different qualities of PCK with more rigour. Second, we see (indication of category 4) that despite of a good understanding of the situation, the decision-process may lead to incoherent teacher actions. The problems in phrasing helpful teacher actions may also partly be attributed to a lack of usable teacher knowledge. The findings also indicate that a closer look on teacher-specific skills for decision-making can help to explain the difficulties.

The results of this case study should be considered as only tentative as sample size, possible selection effects regarding the overall sample as well as the design of the study constitute limitations. To overcome these limitations, further studies will be conducted. Consequently, we are currently gathering data of a larger sample of pre- and in-service teachers aiming on both corroborating our findings and being able to describe in more detail the differences between more and less competent mathematics teachers. That knowledge could not only improve current models of teacher competence, but also teacher education itself as it may yield starting-points for fostering pre-service teachers' abilities to apply their knowledge already in an early stage of teacher education.

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