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The research presented in this paper focuses on prospective elementary teachers' proceeding in one-on-one diagnostic mathematics interviews. It goes beyond measuring the accuracy of teachers' judgments of students' achievements and analyses qualitative facets of diagnostic competence. Participants of mathematics methods courses were asked to prepare and conduct diagnostic interviews with children in grade one and reflect on their diagnostic proceeding afterwards. Findings of the research affiliated to this university teaching project lead to a model of strategic elements in PTs diagnostic proceeding and suggest types of diagnostic strategies. These may be realized or deliberately used to foster a sensitive qualitative diagnostic attitude.

Keywords: Prospective teachers, teacher education, analyses in one-on-one interviews, children in grade one, diagnostic strategies.

INTRODUCTION

Shulman (1986) or Ball and colleagues (2008) suggest distinct domains of teacher knowledge and point out *pedagogical content knowledge* (PCK) to be an integral element of teacher knowledge. PCK includes knowledge about *common* mathematical conceptions or misconceptions that are frequently encountered in the classroom. An interesting option to gain this kind of knowledge arises from teacher education settings where teachers examine *individual* cases: Analyzing a student's error to understand the underlying misconception refers to *knowledge of content and students* (KCS), which is regarded as a sub-domain of PCK by Ball and colleagues (2008, p. 403). Thus, the capability of "eliciting and interpreting individual students' thinking" can be found among the set of "high-leverage practices" (University of Michigan, 2015; Cummings Hlas & Hlas, 2012).

In this sense, identifying unique facets of the specific individual situation may contribute to a better understanding of widespread (mis)conceptions and provide an improvement of KCS (e.g., Peter-Koop & Wollring, 2001; Hunting, 1997). Dealing with individual cases may thereby foster the development of a teacher's diagnostic attitude and improve his or her teaching practices: If a teacher has detailed information on a student's individual mathematical concepts at his or her disposal, he or she gets the chance to design appropriate learning opportunities for this student. In this sense, diagnostic competence is an important element of adaptive teaching competence (Wang, 1992).

Recent studies concerning teachers' diagnostic competences mainly focus on measuring the accuracy of teachers' judgments (e.g., regarding a rank order within classes; cf. Südkamp et al., 2012). In these studies, diagnostic competence is "operationalized as the correlation between a teacher's predicted scores for his or her students and those students' actual scores" (Helmke & Schrader, 1987, p. 94). Individual mathematical learning processes which teachers try to capture during phases of concrete diagnostic activities are scarcely touched upon this understanding of the concept of diagnostic competence. But, focusing on high-leverage practices and on approaches of informal formative assessment (cf. Ginsburg, 2009), *how* do teachers arrive at a diagnosis of a student's conception via oral questioning or observation? As differences in accuracy might be due to teachers' different ways of diagnosing and analyzing, *how* do they get to an appropriate interpretation of a child`s utterances or how can they be helped to achieve appropriate diagnoses?

THEORETICAL FRAMEWORK

Diagnostic interviews in research, in the classroom and in teacher education

One-on-one diagnostic mathematics interviews stem back to the clinical method of interviewing developed by Jean Piaget. For educational research, one-on-one interviews provide a powerful method to gain insight into children's mathematical conceptions. Following a qualitative research paradigm, these conceptions can be interpreted from the children's utterances and activities they show while working on a problem. (cf. Hunting, 1997; Ginsburg, 2009).

To cope with the challenges of every-day classroom situations, teachers need a sensitive, constructivist views of their students' individual mathematical thinking and their progress in developing mathematical concepts. Thus, diagnostic interviews not only serve as a research method, but have also reached the classroom and may appear as little talks between teacher and student during a phase of individual working. In addition, research-based frameworks (e.g., concerning learning trajectories) resulted in the design of standardized task-based interviews to assess the range and depth of children's thinking in the context of mathematics learning in school. In these task-based interviews, in-service teachers actively explore facets of children's approaches to mathematics tasks. Prepared interview tools and empirically based growth points for the analysis guide teachers through these one-on-one diagnostic interviews and provide them with weighty arguments for their diagnoses. This may not only foster children's mathematical learning but also serve teachers' professional development (e.g., ENRP task-based assessment interview/ CMIT/EMBI; cf. Clarke, 2013; Bobis et al., 2005; Peter-Koop et al., 2007).

High-quality programs for prospective teachers (PTs) engage them in concrete tasks which also include tasks of assessment or observation and focus on students' learning processes (e.g., Borko et al., 2010). Thus, studying students' mathematical conceptions in one-on-one interviews (which the PTs *themselves* prepare, conduct and analyze) offers substantial learning opportunities (cf. Prediger, 2010; Sleep & Boerst, 2012). Being involved in research projects that include interview assessments may also support the development of a sensitive diagnostic attitude (cf. Jungwirth et al., 2001; Peter-Koop & Wollring, 2001).

A process-oriented approach to diagnostic competence

Expertise in the area of diagnosing children's mathematical conceptions must not be restricted to teachers' accuracy in measuring children's achievements. It should additionally include rather vague aspects like diagnostic sensitivity, curiosity, an interest in children's emerging understanding and learning or the aptitude to gather and interpret relevant data in non-standardized settings (e.g., Prediger, 2010). Aiming at a framework to analyze processes and facets of diagnosing, it seems helpful to take a model into account which points out phases of the diagnostic process. In this sense, acting within a diagnostic situation in a one-on-one interview which intends to enlighten students' (mathematical) thinking can be regarded as an integral element of a circular process consisting of three dimensions, each including several components (Klug, 2011; Klug et al., 2013): Before trying to sum up information for a substantial diagnosis, it is crucial that the teacher sets the aim of the diagnosis in a preparatory *pre-actional phase*. This includes that the teacher should intentionally aim to watch the individual student's learning processes and therefore choose appropriate tasks and methods. The following *actional phase* includes data collection and data interpretation. Finally, the *post-actional phase* implies taking the necessary action from the data collection and interpretation in the actional phase (e.g., giving feedback, planning actions to foster). Activities in this phase also serve to prepare a repeated run through the diagnostic macro-process.

Cognitive elements in the micro-processes of the actional phase of diagnosing

Researchers in mathematics education have partially specified the challenges that in-service or prospective teachers face within such diagnostic macro-processes: Obviously, teachers actively do "construct knowledge by observation, experience, transfer and interrelation." (Bräuning & Nührenbörger, 2009, p. 945). Furthermore, there is a strong interest in the field of noticing and interpreting which can be analyzed when PTs face students' mathematical solutions. In this field, Ribeiro and colleagues (2013) investigate prospective teachers' *interpretative knowledge* which they regard to be part of SCK (*specialized content knowledge*, specified as sub-domain of content knowledge by Ball and colleagues (2008)). In these studies, the concept of interpretative knowledge is related to the ability of noticing and the authors point out that

many PTs "find difficulties in interpreting children's solutions different from their own solution". Crespo (2000) and Kuhlemann (2013) offer similar results.

Focusing on *micro-processes within the actional phase in a one-on-one mathematics interview*; *collecting* data, *interpreting* and drawing *conclusions* have a major impact on the diagnosis which is derived from an interview and are likely based on different kinds of knowledge (e.g., KCS or SCK, see Figure 1). Here, proceeding in a one-on-one diagnostic interview is vitally influenced by cognitive processes and a person's (verbal) articulation (e.g., ways of questioning, confirming). Intentional decisions (e.g., switching between tasks) may reveal facets of the ongoing internal considerations.

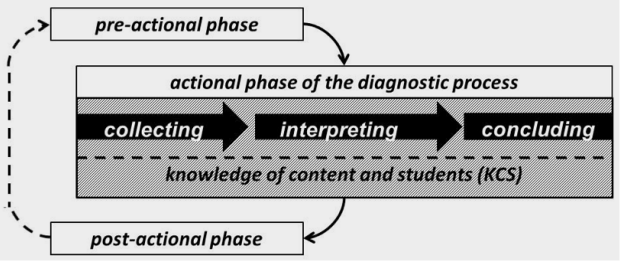

Figure 1: Differentiating the micro-process in the actional phase of diagnosing

Moyer and Milewicz (2002) identified general questioning categories (check-listing/instructing/probing and follow-up questions) used by PTs while collecting data in one-on-on diagnostic interviews. As there is no direct access to students' conceptions in these interviews, they "must be reconstructed by interpreting their utterances" (Prediger, 2010, p. 76) as "the interviewer attempts to construct a model of the student's mathematical knowledge" (Hunting, 1997, p. 149). Consequently, it is also important to reach a substantial perception of the diagnostic situation while interpreting. According to Barth and Henninger (2012, p. 51), this "includes the ability to structure the situation cognitively, the ability to change the focus of attention and the willingness and ability to adopt other perspectives" which leads to the generation and testing of hypothesis. Moreover, there is a demand "to know which information or knowledge sources play the most important role during the process of diagnosing students' learning prerequisites" (Barth & Henninger, 2012, p. 50). Yet, the implications of "gathering information, acting systematically" (Klug et al., 2013, p. 39) within the *actional phase* are not entirely clear for one-on-one interviews in mathematics education, so far.

RESEARCH QUESTIONS

The project *diagnose:pro* which is setting the frame for the study presented here emphasizes the need to sensitize prospective elementary mathematics teachers (PTs) to varieties, ranges and depth of young children's mathematical thinking. Therefore, graduate students (Master of Education) prepare, conduct and analyze one-on-one interviews about arithmetic problems with first-graders. These activities were part of a specific teacher education project at the University of Braunschweig (2011–2014) which is, due to space limitations, not presented in detail here. One part of the affiliated research project focuses on cognitive diagnostic strategies PTs use in their reflection and during the analysis of those interviews. To reach an empirically grounded theoretical framework for a qualitative view of PTs' cognitive activities in one-on-one interviews with children, the main purpose is to detect traits of these diagnostic strategies:

- What cognitive elements characterize the PTs' diagnostic strategies when diagnosing individual arithmetic approaches in one-on-one mathematics interviews with children at the beginning of grade one?
- Which types of (flexibly used) diagnostic strategies can be reconstructed from interviews they or others have been conducting?
- What kind of (pedagogical content) knowledge is included during the diagnostic proceeding?

METHODS

Making use of various approaches, data collection has been ongoing since 2011 and started with explorative studies via video-vignettes which led to written (mostly open) diagnostic comments of 31 PTs on diagnostic scenes. As analyzing these "diagnostic products" was not sufficient to answer the posed research questions, the following data-collection was shifted to video- and audiotaped peer-talks about mathematic diagnostic interviews: Here, students of two university courses (Master of Education, 28 participants in 2012) were asked to discuss about diagnostic scenes in video-vignettes. Finally, seven PTs (who had conducted a di-

agnostic mathematics interview with a first-grade child themselves) agreed to take part in retrospective interviews which complemented data collection in 2013. These interviews resembled methods used by Moyer and Mielewicz (2002). All PTs attended a mathematics methods course in the last year of their university studies which provided the opportunity to conduct individual diagnostic interviews with up to six first-graders per PT in cooperation with an elementary school. First drafts of these interviews were prepared at the beginning of the course where the PTs could refer to previous theoretical work on concepts of arithmetic learning trajectories and the method of task-based mathematics interviews (e.g., EMBI; Peter-Koop et al., 2007).

With only general advice at the beginning of the retrospective interviews, the PTs were asked to "analyze the interview" while watching the video-recording of an interview they had conducted. The PT was requested to stop the video at any scene in order to comment on the diagnosis he or she would derive from this specific situation or related observations. If comments were rather short or pure in detail, the PT was asked to explain what knowledge, information or evidence warranted his or her hypothesis. In addition to this concrete task (diagnosis of the child's conception or knowledge), the PT reflected on his or her proceeding in a more general way: Referring to the preliminary design of the interview, the PT was asked to comment on the choice of tasks selected, the wording of questions, on their own gestures or on deviations from the sketch. All re-interviews' analyses are based on Grounded Theory methodology and methods including open, axial and selective coding (cf. Corbin & Strauss, 1990). The interpretation, coding and contrasting comparison of the data are supported by ATLAS.ti which enables the research team to directly code video-data.

FIRST RESULTS

Analyses of the study's data support the notion that cognitive elements of PTs' approaches to diagnosis in one-on-one interviews often resemble basic processes in qualitative data analysis. This includes acts like *collecting*, *interpreting* and *concluding* within diagnostic micro-processes (see Figure 1). Furthermore, the findings contribute to the identification of sub-categories of collecting, interpreting or concluding and to interrelations among these sub-categories (see Figure 3). Excerpts from re-interviews with Ann and Sue, Master students in their last year of studies, exemplify facets of *interpreting* within the diagnostic micro-process of the actional phase.

Facets of interpreting: Comparing and contrasting

In her interview with six-year old Tom, Ann offers empty boxes for ten eggs and some chestnuts. The boxes of ten are partitioned in four fields (see Figure 2) since Ann intends to find out how children use these structures for counting. She assumes the children to use abbreviated enumeration, i.e, counting strategies including subitizing parts of an amount (cf. Besuden, 2003). Ann stops the video and comments on a scene where she has just put five chestnuts into the box (forming a row). Tom is asked to add further chestnuts in order to get a result of eight and fills two, then one more into the box. Answering Ann, he remarks "Because I left two free, one more'd be nine, then ten."

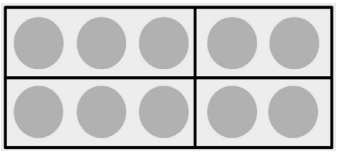

Figure 2: Structured box

> Ann (07:08): And there I noticed that he, eh, always took ten as a starting point for the higher numbers, well, for eight and a moment ago for nine. He remembers, okay there are ten in the package, and then he always counts backwards.

In her comment, Ann compares and refers to Tom's previous work ("a moment ago"). *Comparing* details to a child's previous utterances or actions, to that of others or to the PTs own concept may also occur in terms of *contrasting* different scenarios:

> Ann (08:30): Here, he saw, okay, there are four in one box and there are another four in the second box, well, four plus four equals eight, but he didn't do it that way in the next task. There he'd count single ones, it was done quite differently.

Facets of interpreting in a diagnostic micro-process: Coding

Sue uses the same kind of tasks in her interview with six-year old Ben. She wants him to find out how many

chestnuts have to be added to four chestnuts (which are presented in the "square" on the right side of the box) to get a result of seven. Ben replies by first adding two (forming a "rectangle"), then one more to reach seven (Ben: "These are six, then seven."). Sue codes these activities by creating and applying the new term "auxiliary calculation":

> Sue (05:40): Responding to my enquiry, how he'd done this, now, how many he'd add, actually, I only wanted to hear three, well, he would seize on his, let's say "auxiliary calculation", six plus one equals seven.

PTs are similarly coding observed phenomena as they try to grasp unfamiliar, but obviously central aspects. Codes are often referred to later in the interviews (e.g., Sue's reference to the code "auxiliary calculation", 22:30) and also include substitutions for established terms (e.g., "shortcut" instead of "subitizing").

Facets of interpreting in a diagnostic micro-process: References to knowledge of content and students (KCS)

To describe the children's performances in the re-interview, PTs also try to make use of standardized terms that refer to previously acquired KCS and seize on theoretical concepts that were studied in the methods course before conducting the interviews:

> Sue (04:50): Well, at the beginning, Ben definitely used counting strategies. He saw those four and went on counting from that summand. He noticed, okay, if I add two then I'll get six, thus, he didn't go like "five...six", but he said, okay, two, that's six.

Although details of the counting strategy "counting on by steps of two" are not reflected here, referring to mathematical KCS tends to be an important element of PTs' diagnostic strategies: PTs do use information from their teacher preparation courses. They retain general knowledge of children's development of mathematical conceptions (e.g., "understanding of quantities"), but then remain unfocused in supporting their interpretation with this knowledge:

> Ann (15:17): But, Tom doesn't have, eh, a complete understanding of quantities at his disposal, partly he did, partly he didn't. It's when a child notices that a number is now, eh, bigger than the number before, or that one can draw conclusions from one equation to the next, that is connected to the first one.

Types of diagnostic strategies

Following Grounded Theory methodology, distinct types of diagnostic strategies with a stress on different elements of diagnostic proceeding (i.e., on the exemplified (sub-) categories) are detected. As indicated by the arrows in Figure 3, PTs' diagnostic strategies are far from a linear process and may be driven by general dimensions of diagnostic strategies (e.g., topographic or symptomatic search; Cegara & Hoc, 2006).

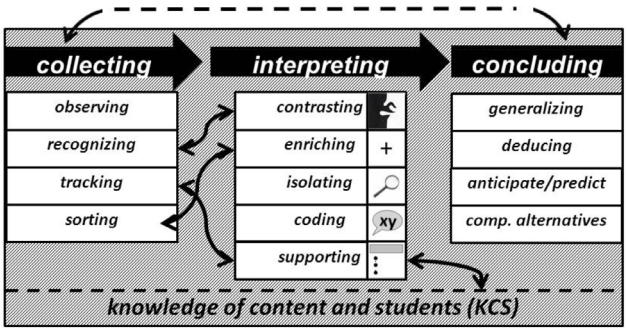

Figure 3: Sub-categories of collecting, interpreting and concluding

Following the strategy *descriptive collector*, the PT focuses on collecting and describing the actions, neglects both interpreting and concluding, and searches rather typographically. A *concluding collector* strategy is characterized by skipping elements of interpretation as collecting leads directly to conclusions which resembles findings of Crespo (2000). Symptomatic searches occur when elements of interpreting prevail in a *branched interpretation*. Here, interpreting, collecting and concluding are intertwined and frequently linked to KCS.

DISCUSSION

The findings of the study provide evidence of sub-categories of collecting, interpreting and concluding within micro-processes of the actional phase of diagnosing. They point at KCS within these processes and hint at a variety of strategy types. Thus, results enrich, for example, the idea of "interpreting" in the actional phase of diagnosing suggested by Prediger (2010) or Barth and Henninger (2012).

Bearing in mind that the findings are restricted to a particular type of tasks (arithmetic issues) and that they refer to a rather small number of participants (n=28 in peer-talks; n=7 individual interviews), the study outlines new topics in the field of teachers' professional development: It raises the hypothesis that reflecting on facets of interpreting in one-on-one interviews enhances PTs diagnostic sensitivity. This may increase their knowledge of assessing children's mathematical abilities and contribute to the consideration and implementation of "high-leverage practices": An awareness of "strategic diagnostic tools" might help to master diagnostic challenges in the classroom. Thus, further activities of the project *diagnose:pro* will explore how the findings (elements of diagnostic strategies/types of strategies) can be taken up in university courses and contribute to appropriate diagnoses of children's concepts in one-on-one interviews. Further steps also include using the developed model to qualitatively evaluate changes of PTs' interpretations over the duration of university courses and to analyze what leads to changes in PTs' diagnostic strategies.

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