QUALITATIVE FACETS OF PROSPECTIVE ELEMENTARY TEACHERS' DIAGNOSTIC COMPETENCE: MICRO-PROCESSES IN ONE-ON-ONE DIAGNOSTIC INTERVIEWS

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Going beyond measuring accuracy of teachers' judgments of students' achievements, this paper focuses on how prospective elementary teachers proceed in one-on-one diagnostic mathematics interviews. As part of the project ***diagnose:pro****, prospective elementary teachers (PTs) conduct diagnostic interviews with children in grade one and reflect on diagnostic strategies afterwards. Findings of the study lead to a model of strategic elements in diagnostic proceeding and suggest types of diagnostic strategies. It is also discussed how awareness of diagnostic strategies can be developed to foster sensitive every-day qualitative diagnostic attitudes in PTs.*

INTRODUCTION

Based on the domains suggested by Shulman (1986) or Ball et al. (2008), *pedagogical content knowledge* (PCK) includes knowledge about *common* mathematical conceptions or misconceptions that are frequently encountered in the classroom. Besides theoretical instructions in teacher education or through a longer period of teaching experience, acquisition of this knowledge can also be enhanced as teachers examine *individual* cases: Analyzing a student's error to find out more about the underlying misconception refers to *knowledge of content and students* (KCS), which is regarded as subdomain of PCK by Ball et al. (2008). Identifying unique facets of such individual cases may contribute to the understanding of widespread (mis)conceptions (e.g. Peter-Koop & Wollring, 2001; Hunting, 1997), thereby serving the elaboration of KCS and fostering the development of a teacher's diagnostic attitude.

Diagnostic competence is an important element of adaptive teaching competence since detailed information on a student's individual conception can support the design of appropriate learning opportunities (Wang, 1992). Recent studies concerning teachers' diagnostic competence mainly focus on measuring 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). Contrary to this paradigm, there is a wide field in mathematics education research which deals with qualitative aspects of children's wide-ranging learning developments. However, little is known about the *processes of diagnosing* which lead teachers to the evaluation of an individual student's learning development in these process-oriented observations: Focusing on approaches of informal formative assessment (cf. Ginsburg, 2009), *how* do teachers arrive at a diagnosis of a student's

2014. In Nicol, C., Oesterle, S., Liljedahl, P., & Allan, D. (Eds.) Proceedings of the Joint Meeting of PME 38 and PME-NA 36,Vol. 5, pp. 41-48. Vancouver, Canada: PME.

conception via oral questioning or observation? As differences in accuracy might be due to teachers' different ways of diagnostic proceeding and analyzing, *how* do they get to an appropriate interpretation of a child`s utterances or can be helped to do so?

Setting the frame for this report, the project ***diagnose:pro*** 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 children in grade one. One part of the project focuses on the cognitive diagnostic strategies PTs use in the reflection of those interviews. Thereby, it responds to the detected lack of knowledge regarding qualitative facets of interpretation in diagnostic situations. Findings in this scarcely explored domain are likely to strengthen the "power of task-based one-on-one interviews" (Clarke, 2013) in daily practice.

THEORETICAL FRAMEWORK

Diagnostic mathematics interviews in teacher education

As teachers have to cope with an increasingly complex and demanding professional landscape, beginners and experienced teachers need to develop a sensitive, every-day constructivist view on their students' individual mathematical thinking and progress. High-quality professional development engages teachers in concrete tasks (e.g. tasks of assessment or observation) and focuses on students' learning processes (Borko et al., 2010). Preparing, conducting and analyzing one-on-one interviews provide novices with substantial learning opportunities as they study students' mathematical conceptions (cf. Prediger, 2010; Sleep & Boerst, 2012). Developing a sensitive diagnostic attitude is also supported by involving PTs in research projects that include interview assessments (cf. Jungwirth et al., 2001; Peter-Koop & Wollring, 2001).

Diagnostic interviews not only serve as a method in mathematics research and teacher education, but have also reached the classroom. Research-based frameworks (e.g. concerning learning trajectories) resulted in the design of standardized task-based interviews to assess children's thinking in the context of mathematics learning in school – in short, to provide teachers with weighty arguments for sound diagnoses and for the preparation of adaptive learning arrangements. Here, interview tools and the prepared analysis (via empirically based growth points) serve to improve teachers' professional development as they are encouraged to actively explore qualitative facets of children's approaches to mathematics tasks (e.g. ENRP task-based assessment interview/CMIT/EMBI; cf. Clarke, 2013; Bobis et al., 2005; Peter-Koop et al., 2007).

A process-oriented approach to diagnostic competence

Ensuing a comprehensive understanding of diagnostic competence, expertise in this area reaches beyond teachers' accuracy in measuring students' achievements. Besides relating diagnostic competence to KCS as part of PCK, it additionally includes rather vague aspects like diagnostic sensitivity, curiosity, an interest in students' emerging understanding and learning or the aptitude to gather and interpret relevant data in

non-standardized settings (e.g. Prediger, 2010). 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 multidimensional spiral process (Klug, 2011; Klug et al., 2013). According to this model, a *pre-actional phase* (e.g. considerations of preparing diagnostic activities; choice of tasks/methods) prepares an *actional phase* (including data collection and data interpretation) that is followed by a *post-actional phase*. The latter implies taking the necessary action from data collection and interpretation which feeds to the design or the evaluation of a concept for an individual support in a repeated run through phases of 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 teachers face within such diagnostic macro-processes. Focusing on *micro-processes within the actional phase*; **collecting** data, **interpreting** and drawing **conclusions** have deep impact on the diagnosis from an interview and are likely based on different kinds of knowledge (e. g. KCS, see fig. 1). In this sense, proceeding in a one-on-one diagnostic interview is vitally influenced by cognitive processes. A person`s (verbal) articulation (e.g. ways of questioning, confirming) and intentional decisions (e.g. switching between tasks) may reveal facets of these ongoing internal considerations.

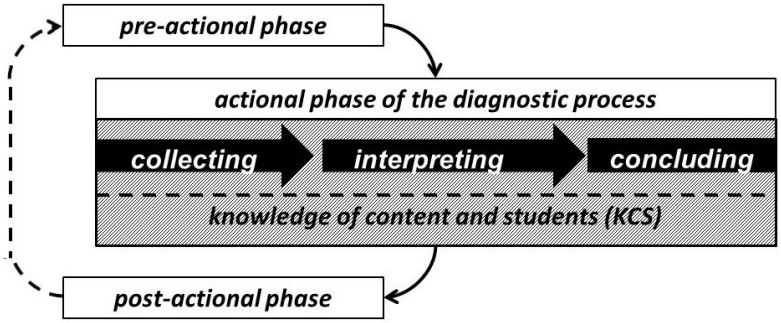

Figure 1: Differentiating the micro-process in the actional phase of diagnosing.

Moyer & Milewicz (2002) identified general questioning categories (check-listing/ instructing/probing/follow-up questions) used by PTs while collecting data in 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). Thus, it is also important to reach a substantial perception of the diagnostic situation while interpreting. According to Barth & Henninger (2012), 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" (p. 51) which leads to the generation/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). But the implications of "gathering information, acting systematically" (Klug et al., 2013, p. 39) within the *actional phase* are not yet entirely clear for one-on-one interviews in mathematics education.

RESEARCH QUESTIONS

Aiming at an empirically grounded theoretical framework for a qualitative view on PTs' cognitive activities in one-on-one interviews with children, the main purpose of the partial study presented in this paper is to detect traits of 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 knowledge (e.g. KCS) is used during the diagnostic proceeding?

METHODS

Data collection since 2011 included studies via video-vignettes (which led to written comments of 31 PTs on diagnostic scenes) and switched to video/audiotaped peer-talks among 28 graduate students about video-scenes of diagnostic interviews in 2012. Until fall 2013, retrospective interviews with seven PTs who had conducted a diagnostic mathematics interview with a first-grade child (cf. Moyer & Mielewicz, 2002) complemented data collection (cf. Reinhold, 2013). All PTs attended a mathematics methods course in the last year of their university studies (Master of Education). This course 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 point 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 PTs were asked to comment on the choice of some selected tasks, on the wording of questions, on their own gestures or on deviations from the sketch. What prompted them to react to a child's response? What was taken into account to confirm a diagnosis?

The analyses of all re-interviews are based on Grounded Theory methodology and methods which include open, axial and selective coding (cf. Corbin & Strauss, 1990). The interpretation, coding and contrasting comparison of the data are supported by the software ATLAS.ti which enabled the research team to directly code video-data.

FINDINGS

Analyses of the study's data support the notion that cognitive elements of PTs' ways of diagnostic proceeding 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 fig. 1). Furthermore, the findings contribute to the identification of sub-categories of collecting, interpreting or concluding and to interrelations among these sub-categories (see fig. 3). Excerpts from re-interviews with Ann and Sue, master's students in their last year of studies, display exemplary *facets of* ***interpreting*** *within the diagnostic micro-process of the actional phase*.

Facets of interpreting in a diagnostic micro-process: Comparing and contrasting

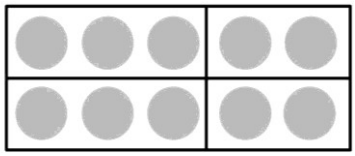
Fig. 2: Structured box

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 fig. 2) since Ann intends to find out how children use these structures for counting or for 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."

> 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.[1]

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 actions by creating 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.

[1] All interview excerpts are translated into English by the author.

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

Facets of interpreting: 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. These refer to previously acquired KCS and seize on theoretical concepts that were studied in the methods course before conducting the interviews:

> Sue (04:50): At the beginning, Ben definitely used counting strategies. He saw those four and went on counting from that summand. He noticed, if I add two 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 KCS tends to be an important element of PTs' diagnostic strategies: PTs do use information from their teacher preparation courses. They partially retain general knowledge of children's development of mathematical conceptions, but often remain unfocused in supporting their interpretation with this knowledge as we see in Ann's explanations of the term "understanding of quantities":

> 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 fig. 3, PTs' diagnostic strategies are far from being a linear process and may be driven by general dimensions of diagnostic strategies (e.g. topographic or symptomatic search; Cegara & Hoc, 2006).

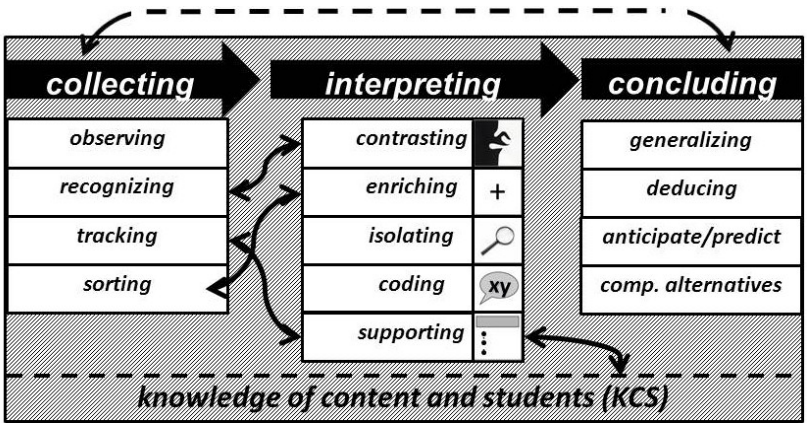

Figure 3: Sub-categories of collecting, interpreting and concluding.

Following the strategy *descriptive collector*, the PT searches rather typographically, focuses on collecting and describing the child's actions and neglects both interpreting

and concluding. A *concluding collector* strategy is characterized by skipping elements of interpretation as collecting directly leads to conclusions. 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, point at KCS within these processes and hint at a variety of strategy types. Thus, results enrich the idea of "interpreting" in the actional phase of diagnosing suggested by Prediger (2010) or Barth & Henninger (2012). Bearing in mind that the findings are restricted to a particular type of tasks (arithmetic) 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 proceeding in one-on-one interviews enhances PTs diagnostic sensitivity and increases their knowledge of assessing children's mathematical abilities. As an integral element of PCK, this might include awareness of "strategic diagnostic tools" which 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.

References

Ball, D. L., Thames, L., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389-407.

Barth, C., & Henninger, M. (2012). Fostering the diagnostic competence of teachers with multimedia training – A promising approach? In I. Deliyannis (Ed.), *Interactive multimedia* (pp. 49-66). Rijeka, Croatia: InTech.

Besuden, H. (2003). Rechnen mit Eierkartons. *Grundschule*, *35*(5), 51-54.

Bobis, J., Clarke, B., Clarke, D., Thomas, G., Wright, R. B., Young-Loveridge, J., & Gould, P. (2005). Supporting teachers in the development of young children's mathematical thinking. *Mathematics Education Research Journal*, *16*(3), 27-57.

Borko, H., Jacobs, J., & Koellner, K. (2010). Contemporary approaches to teacher professional development. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International encyclopedia of education* (Vol. 7, pp. 548-556). Oxford, England: Elsevier.

Cegarra, J., & Hoc, J. M. (2006). Cognitive styles as an explanation of experts' individual differences: A case study in computer-assisted troubleshooting diagnosis. *International Journal of Human-Computer Studies*, *64,* 123-136.

Clarke, D. (2013). Understanding, assessing and developing children's mathematical thinking: task-based interviews as powerful tools for teacher professional learning. In A. M. Lindmeier & A. Heinze (Eds.), *Proc. 37th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol. 1, pp. 17-30). Kiel: PME.

Corbin, J., & Strauss, A. L. (1990). *Basics of qualitative research: Grounded Theory procedures and techniques.* Newbury Park, CA: Sage Publications.

Ginsburg, H. P. (2009). The challenge of formative assessment in mathematics education: Children' s minds, teachers' minds. *Human Development*, *52*, 109-128.

Helmke, A., & Schrader, F.-W. (1987). Interactional effects of instructional ability and teacher judgement accuracy on achievement. *Teaching & Teacher Education*, *3*(2), 91-98.

Hunting, R. P. (1997). Clinical interview methods in mathematics education research and practice. *Journal of Mathematical Behavior*, *16*(2), 145-165.

Jungwirth, H., Steinbring, H., Voigt, J., & Wollring, B. (2001). Interpretative classroom research in teacher education. In H.-G. Weigand, E. Cohors-Fresenborg, A. Peter-Koop, H. Maier, K. Reiss, G. Törner, B. Wollring, & K. Houston (Eds.), *Selected papers from the Annual Conference of Didactics of Mathematics, Regensburg, 1996* (pp. 49-56). Hildesheim: Franzbecker.

Klug, J. (2011). *Modelling and training a new concept of teachers' diagnostic competence.* Darmstadt: TU Darmstadt.

Klug, J., Bruder, S., Kelava, A., Spiel, C., & Schmitz, B. (2013). Diagnostic competence of teachers: A process model that accounts for diagnosing learning behavior tested by means of a case scenario. *Teaching and Teacher Education*, *30*, 38-46.

Moyer, P. S., & Milewicz, E. (2002). Learning to question: categories of questioning used by preservice teachers during diagnostic mathematics interviews. *Journal of Mathematics Teacher Education*, *5*, 293-315.

Peter-Koop, A., & Wollring, B. (2001). Student teacher participation in interpretative classroom research. *Mathematics Teacher Education and Development*, *3*, 4-15.

Peter-Koop, A., Wollring, B., Spindeler, B., & Grüßing, M. (2007). *Elementarmathematisches Basisinterview*. Offenburg: Mildenberger.

Prediger, S. (2010). How to develop mathematics for teaching and for understanding. *Journal of Mathematics Teacher Education*, *13*(1), 73-92.

Reinhold, S. (2013). Prospective primary mathematics teachers' diagnostic competence: modelling the process. In A. M. Lindmeier & A. Heinze (Eds.), *Proc. 37th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol. 5, p. 151). Kiel, Germany: PME.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Sleep, L., & Boerst, T. A. (2012). Preparing beginning teachers to elicit and interpret students' mathematical thinking. *Teacher and Teacher Education*, *28*, 1038-1048.

Südkamp, A., Kaiser, J., & Möller, J. (2012). Accuracy of teachers' judgments of students' academic achievement: A meta-analysis. *Journal of Educational Psychology*, *104*, 743-752.

Wang, M. C. (1992). *Adaptive teaching strategies: Building on diversity*. Baltimore: Brookes.