Qualitative Facets of Prospective Elementary Teachers' Diagnostic Proceeding: Collecting and Interpreting in One-on-one Interviews

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The research presented in this paper focuses on the cognitive diagnostic strategies that prospective elementary mathematics teachers (PTs) use in their reflections of one-on-one diagnostic interviews with children in grade one. Thereby, it responds to the detected lack of knowledge regarding qualitative facets of diagnostic proceeding in interview assessments. Results include facets of collecting data and facets of interpreting within a diagnostic micro-process. The discussion takes up the relevance of these findings for teacher education.

The challenges of every-day classroom situations include the design of appropriate learning opportunities, which refers to adaptive teaching competence and includes diagnostic competence (cf. Wang, 1992). To meet these demands, beginners and experienced teachers benefit from a constructivist view of their students' individual progress in developing mathematical concepts. A powerful method to gain particular information on children's mathematical conceptions is provided with diagnostic one-on-one interviews which stem back to the clinical method of interviewing developed by Jean Piaget (cf. Ginsburg, 2009). Standardised task-based interviews enable access to the range and depth of children's thinking as (in-service) teachers actively explore qualitative facets of children's approaches to mathematical tasks. Prepared interview tools and empirically based growth points for the analysis may guide through these one-on-one interviews and thereby foster teachers' professional development (e.g., ENRP task-based assessment interview/CMIT/EMBI; cf. Clarke, 2013; Bobis et al., 2005; Peter-Koop et al., 2007).

Additionally, there is a need to sensitise *prospective* elementary mathematics teachers (PTs) for the variety, range, and depth of young children's mathematical thinking and to qualify them for informal formative assessment. In this sense, preparing, conducting, and analysing students' mathematical conceptions in one-on-one interviews offers substantial learning opportunities and supports the development of PTs' diagnostic attitude (cf. Peter-Koop & Wollring, 2001; Prediger, 2010; Sleep & Boerst, 2012). Yet, qualitative facets of the diagnostic proceeding during a one-on-one interview have only been scarcely studied so far. This includes facets of interpretation and facets of data collection; that is, the question how actions or utterances are taken up before being used for interpretation.

Theoretical Framework

The Concept of Diagnostic Competence and Domains of Teacher Knowledge

Recent studies on diagnostic competence mainly focus on measuring the accuracy of teachers' judgments (cf. Südkamp et al., 2012). With an emphasis on those numerical indicators, diagnostic competence is most often "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). Here, questions of *qualitative* aspects of diagnostic competence and its acquisition remain unanswered, and *processes of diagnosing* which lead to the evaluation of an individual student's development are not taken into account.

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Ball et al. (2008) suggest that *pedagogical content knowledge* (PCK) includes knowledge about *common* mathematical conceptions or misconceptions that are frequently encountered in the classroom. Options to achieve this kind of knowledge may arise from analysing *individual* cases, which refers to *knowledge of content and students* (KCS) defined as subdomain of PCK (Ball et al., 2008, p. 403). Thus, the capability of "eliciting and interpreting individual students' thinking" can be found among the set of "high-leverage practices" novices should be familiarised with (cf. Ball et al., 2009; Cummings Hlas & Hlas, 2012). Sleep & Boerst (2012) conceptualise this particular "high-level practice" as subcomponent of the domain "assessing student thinking" (p. 1039). In this sense, analysing an individual's mathematical concept may contribute to a deeper understanding of widespread (mis)conceptions. It may develop KCS, improve a teacher's practices in terms of diagnostic attention, and thereby enrich his or her diagnostic expertise.

Modelling Phases of the Diagnostic Process

In the field of elementary mathematics education research (which intensely deals with *qualitative* aspects of children's wide-ranging learning developments), expertise in this area reaches beyond teachers' accuracy in measuring children's achievements. It additionally includes 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-standardised settings (e.g., Prediger, 2010). Following this process-oriented attitude towards diagnostic competence, activities of formative assessment in a one-on-one interview can be seen as a multidimensional cyclic 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 or methods) prepares an *actional phase* (including data collection and data interpretation), which is followed by a *post-actional phase*. The latter implies taking the necessary action from data collection/interpretation, which leads to the design or the evaluation of a concept for an individual support in a repeated run through phases of this diagnostic *macro-process*.

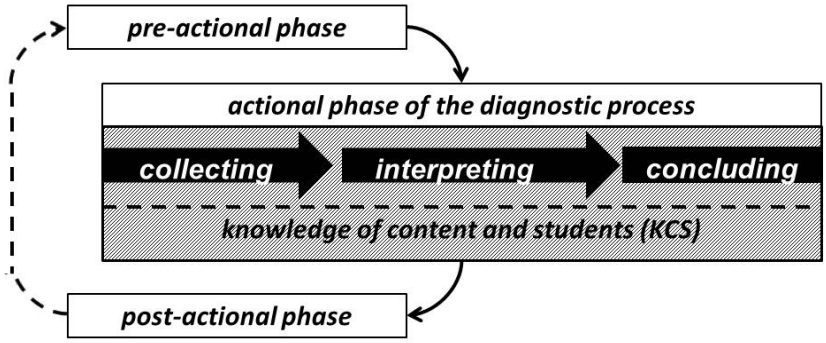

Figure 1. The macro-process of diagnosing and differentiation of the micro-process in the actional phase

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 of diagnosing*, collecting data, interpreting, and drawing further conclusions have deep impact on the diagnose via an interview and are based on different kinds of knowledge (e.g., KCS, see Figure 1). In this sense, proceedings in a one-on-one diagnostic interview are vitally influenced by cognitive processes and 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: When conducting a one-on-one interview, there is no direct access to students' conceptions. Instead and in terms of cognitive activity, those conceptions "must be reconstructed by interpreting their utterances" (Prediger, 2010, p. 76). Yet, we have little knowledge on how this *interpretation* takes place or what is taken into account when an interviewer is "gathering information" (Klug et al., 2013, p. 39). This refers to *collecting and interpreting within the actional phase of the diagnostic process*.

Collecting as a Source for Interpretation and Conclusion

Collecting valuable information is obviously of high importance as this information is the source for interpretation and conclusion. Sleep & Boerst (2012) point out that the available information initially relies on the (previous) choice of tasks for the diagnostic situation as tasks "yield sound and useful information about student learning of particular content" (p. 1038). For one-on-one interviews, these tasks are usually chosen in the pre-actional phase, but they obviously influence opportunities for data collection in the actional phase, too. Moyer & Milewicz (2002) identified general questioning categories (check-listing/instructing/ probing and follow-up questions) used by PTs while collecting data in one-on-one interviews. Furthermore, interpreting within any diagnostic situation is also based on a substantial perception of the diagnostic situation. 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" (Barth & Henninger, 2012, p. 51). Thus, attention and the capability to focus this attention tend to be crucial prerequisites for collecting within the actional phase. Attending as integral element of "professional noticing of children's mathematical thinking" refers to the skill of "being able to recall the details of children's strategies" (Jacobs et al., 2010, p. 172).

In the actional phase of diagnosing in a one-on-one interview, noticing and collecting includes the motivation to listen and watch, the ability to observe with keen eyes, the capability to detect important details, or the attitude to value particular aspects in children's utterances or actions. Yet, little is known about the *facets of collecting* PTs use in one-on-one interviews they prepare and conduct with children: *How* is all this information *gathered*, *what kind of information* is it and what characterises PTs' interpretation as they *act systematically*?

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 project *diagnose:pro* is to detect traits of diagnostic strategies: We intend to find out what cognitive elements characterise the PTs' diagnostic strategies when they diagnose individual arithmetic approaches in one-on-one mathematics interviews with first-graders and try to reconstruct how these strategic elements interact. This paper directs the attention to facets of collecting and interpreting PTs use in their diagnostic proceeding:

- What *kind of information* is collected to supply an interpretation and conclusion during the actional phase of the diagnostic process?
- What *differences in the way this information is collected* can be detected?
- What *facets of interpreting* occur?

- (How) do differences concerning the choice of collected information, concerning the way of collecting or facets of interpreting *influence the type of diagnostic strategies* that can be reconstructed from retrospective interviews?

Methods

In the sense of theoretical sampling (Corbin & Strauss, 2008), data collection was intended to capture the range of PTs' practices and proceedings and focused on re-interviews of one-on-one diagnostic interviews. All PTs attended mathematics methods courses in the last year of their university studies (Master of Education). In cooperation with an elementary school, these courses provided the opportunity to prepare, conduct, and analyse individual diagnostic interviews with up to 6 first-graders per PT. Drafts for these interviews were prepared at the beginning of the course where the PTs could make use of theoretical work on concepts of arithmetic learning trajectories and the method of task-based mathematics interviews (e.g. EMBI; Peter-Koop et al., 2007). Until Autumn 2013, 7 PTs from these courses agreed to take part in retrospective interviews that focused on the video-recording of an interview they had conducted shortly before.

With a deliberately general advice at the beginning of the retrospective interviews, the PTs were asked to *analyse the interview* while watching the video-recording. The interviewee 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. If comments were rather short or pure in detail, the interviewee was asked to explain what knowledge, information, or evidence warranted his or her uttered 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? These retrospective analyses of diagnostic interviews offered the chance to narrow the focus and to pay attention to details. In this sense, PTs' data collection and interpretation obviously differed from real-time practice in an interview that requires being concurrently aware of many more details.

The analysis of all interviews was based on Grounded Theory methodology; therefore, codes were derived from data via open, axial, and selective coding or contrasting comparison of the data. Use of the software ATLAS.ti enabled video-data to be coded directly. To approach the aim of capturing identified characteristics of diagnostic proceeding in whole range ("saturated", Corbin & Strauss, 2008, p. 143), we also include data which consists of written comments of 31 PTs (collected in 2011) and video/audiotaped peer-talks among 28 PTs about video-scenes of diagnostic interviews (collected in 2012).

Findings

Analyses of the study's data supported the notion that cognitive elements of PTs' ways of diagnostic proceeding in one-on-one interviews often resemble processes in qualitative data analysis. This includes acts like *collecting*, *interpreting,* and *concluding* within diagnostic micro-processes (see Figure 1). The findings also contribute to the identification of sub-categories of collecting, interpreting, or concluding and to interrelations among these sub-categories that hint at distinct types of diagnostic strategies.

Facets of Interpreting: Comparing, Contrasting, Coding

Excerpts from re-interviews with Ann and Sue, Masters students in their last year of studies, display exemplary *facets of interpreting within the diagnostic micro-process of the actional phase.*

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, cf. Besuden, 2003) since Ann intends to find out how children use these structures for counting or for abbreviated enumeration (i.e., counting strategies including subitising parts of an amount).

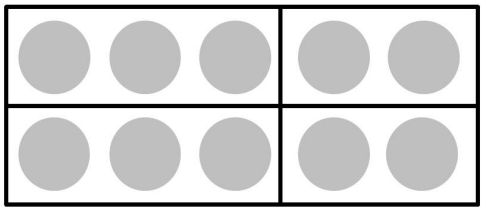

Figure 1. Structured box used in one-on-one interviews Ann and Sue conducted with first-graders

During the re-interview, 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.

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*.

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."

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 subitising).

Facets of Collecting: From Observing to Tracking, Recognizing or Sorting

Findings of the study also reveal that collecting information within the actional phase of a diagnostic micro-process may vary concerning the type of collecting and concerning

the choice of information, as the following excerpts display. In *our* analyses of the PTs' process-oriented analyses we took into account that facets of data collection may include observations which are not mentioned by the PTs. Subconsciously grasped information (e.g., on a child's hidden insecurity, fear to fail when working on the given task, or motivation while working on a task) could also have an influence on a conclusion which is drawn later on. In this sense, we are restricted to focus on the mentioned items. Besides, there is no way to tell data collection in the interview from data collection that can *definitely* be assigned to the re-interview.

PTs' data collection was coded as *observing* when we considered the PTs to watch closely what was happening in the diagnostic situation. All PTs did listen attentively to the child's utterances. They paid attention to significant details, but they most often (also) noticed the (singular) occurrence of micro-incidents that were only loosely connected. In this sense, data collection included various details (see list in table 1) and often ended up in collections that resembled a "colorful bunch of flowers".

On a higher level, facets of collecting coded as *tracking* refer to the skill of following a series of activities or utterances. This includes to follow a child's action over a longer sequence and to maintain attention during the diagnostic situation. This can be seen in the following protocol of Lisa's re-interview on an interview with 6-year old Sam. Sam is asked to take five chips (one side blue, the other side red) and comment on possible ways of displaying an addition with these manipulatives. Sam starts with spreading the chips over the table and starts to sort them, "Three red ones and two blue ones", as Lisa stops the video:

Lisa (01:51):	To comment on this, I'd say he separated red and blue from the beginning and named what was lying on the table.

Later on, Lisa tracks this idea and collects further information from subsequent situations that refer to this issue (sorting and considering position of colors).

Lisa (02:16):	Here, it is clear that he separated the colours from the beginning."
Lisa (10:20):	We wanted them to find that *sorting* the possible additions helps to find all of them, yes and he is arranging them in *any* kind of structure, but … not the one we had intended them to find … But in a way he *does* sort the possible arrangements because in this corner here, the blue ones are closer together. In the next row, the blue ones stick closely together, too, and there the red ones."

PTs' data collection was coded as *recognising* when they repeatedly identified details they had already noticed in previous situations. In contrast to *tracking*, this was restricted to single incidents. *Sorting* in PTs' data collection was identified when they found or intentionally searched for groups or patterns in children's utterances or actions. A further analysis of PTs' comments also reveals a wide range of mentioned details (see examples in Table 1).

Table 1
Various sources for interpretation: What is collected?

Collected	Example
Verbal utterance	"This boy, he was able to identify the summands and he said, 'This number and this number equals this number.'" (Anne)
Activity	"He's drawing a circle around *this* piece of the pattern." (Pam)
(In)correctness of solution	"He was supposed to draw a circle around repeating parts of the pattern, but he failed." (Pam)
(Elements of) strategy	"He used counting strategies, saw 4 and continued counting from that first summand." (Sue)
Eye movement	"He hesitated and looked the other way." (Anne)
(Subtle) movements of lips, head or hands	"I see he is nodding and I guess he's counting up to five here." (Lisa)
Emotional state	"I got the impression he'd start crying." (Anne)
Interviewer's behaviour	"Okay, I liked what I did in this situation as we decided to accept 'wrong' answers, too." (Sue)

Discussion

The study responds to the detected lack of knowledge regarding qualitative facets of diagnostic proceeding in one-on-one interviews and thereby contributes to strengthen the "power of task-based one-on-one interviews" (Clarke, 2013) in daily practice. Even if the reported findings are restricted to a certain type of tasks (arithmetic issues) and that they refer to a rather small number of participants (n=28 in peer-talks; n=7 re-interviews), the study takes *a look behind the s*cenes"of PTs' diagnosing in one-on-one interviews.

PTs' attention was most often attracted by children's obvious or prominent activities or utterances. Items were also collected if the PTs found surprising deviations from what they had expected before. Furthermore, other incidents obviously exactly matched what they had expected. This emphasises the importance of KCS (e.g., knowledge of common (mis)conceptions) as both deviation and alignment can only be stated if there is knowledge which can be used for this comparison. Additionally, this underlines the close relationship between collecting data and reasoning about the collected details (*interpreting* and *concluding*). Yet, this relationship does not necessarily appear as a linear process in PTs' diagnostic proceeding. Instead, PTs may run through these intertwined micro-processes in circles: a type of diagnostic strategy we call a *branched interpretation.* At the same time, we detect other diagnostic strategies, namely the strategy *descriptive collector*, when the PTs focus on collecting and describing the child's actions and neglect both interpreting and concluding.

This reveals *hidden* diagnostic practices that have to be uncovered in order to make them explicit. They are assumed to be of great importance for teacher education. Hence, further investigations in the project *diagnose:pro* will explore, for example, how elements of diagnostic strategies and types of strategies can be taken up in discussions of university courses. This includes making explicit what problems may occur when the strategy *descriptive collector* is predominant. Prospective research in this field will have to examine

if awareness of (elements of) diagnostic strategies and types of diagnostic strategies (including awareness of *strategic diagnostic tools*) may contribute to appropriate interpretations of children's utterances in interviews. This might help to identify a theoretical and practically relevant framework for *high-leverage diagnostic practices* (including various facets of collecting and interpreting) to cope with diagnostic challenges in the classroom.

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