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Developing student teachers' professional knowledge of low attainments' support by "learning-teaching-laboratories"

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This paper presents a study that is part of a project named MaKosi ("Mathematische Kompetenzen sichern"). It aims at the conception and evaluation of a program in which primary student teachers and children who are low attaining in arithmetic work together. The organization refers to a specific form of project seminars called "learning-teaching-laboratories". The study investigates how knowledge of identifying and supporting low attaining children develops by participating in such a program. Qualitative data were generated by learning maps in a pre-post-design and analyzed by a reconstructive pedagogic-icnological image interpretation. The results indicate a sustainable positive development of student teachers' knowledge.

Keywords: Professional development, learning-teaching-laboratories, low attaining students.

Introduction

Concepts of teachers' professionalization are an important focus of current research in mathematics education (e.g., DZLM, 2015). Regarding a specific professional knowledge of teachers, the development of pedagogical content knowledge (PCK) including, in particular, the development of abilities to analyze children's thinking and learning is reputed to be one of the main goals (Sowder, 2007). Moreover, beyond cognitive aspects, some recent approaches on teachers' knowledge consider affective components like beliefs (Kuntze, 2012). Questions that arise from this are, e.g., how student teachers' education on analyzing children's learning trajectories can be realized, and as a result how cognitive and co-cognitive components of student teachers' knowledge develop. In this paper, the attention will be given to the aspects mentioned above by a synthesis of different approaches within a qualitative study: With regard to analyses of children's thinking and learning, the development of primary student teachers' knowledge about the identification and support of low attainments (ISLA) is focused on, since analyzing mistakes is assumed to be a valuable resource in this context (e.g., Ribeiro, Mellone, & Jakobsen, 2013). As to a suitable organization of a professional development program, the approach of "learning-teaching-laboratories" (LTL) is applied, which reflects an important part of current discussions on student teachers' education in Germany (Roth, Lengnink, & Brüning, 2016). Summarized, LTL provide project seminars intertwining student teachers' theoretical and practical education by working with children, i.e., via learning by teaching. The following questions will be investigated: *How can a development of student teachers' knowledge about analyses of children's thinking and learning in mathematics be organized by a connection of ISLA- and LTL-concepts? How does their knowledge by taking part in an ISLA-LTL develop?* First, brief overviews of the theoretical frameworks will be given. On these bases, a LTL-concept will be outlined. Finally, the study's design and results will be subsumed and discussed.

Theoretical frameworks – brief overviews

As to *teachers' professional knowledge*, the classical concept distinguishes between subject matter knowledge, PCK and curricular knowledge. Summarized, PCK refers to knowledge of possibilities regarding teaching subject matters (Shulman, 1986). Independent of certain approaches, there seems to be a consensus on the fact that PCK bridges subject matter knowledge and teaching, and it designates a specific-distinctive manner of teachers' professional knowledge (Brown & Borko, 1992). According to Ball, Thames and Phelps (2008), PCK covers knowledge of content and students, knowledge of content and teaching, and knowledge of curriculum. In particular, the first mentioned aspects provide facets that are connected to analyzing children's thinking and learning as well as to providing an adequate support (Sztajn, Confrey, Wilson, & Edgington, 2012). Because drawing an exact distinction between cognitive aspects regarded by knowledge and affective aspects like beliefs is felt to be difficult, some current research combines both aspects to describe teachers' professional knowledge; inter alia, pedagogical content beliefs (PCB) are described as an equivalent to PCK: Convictions about handling specific instructional situations (Kuntze, 2012) like ISLA. Recent competence frameworks of professional development programs are in line with such approaches. Beyond mathematics-related beliefs, self-oriented ones are considered including components like self-efficacy (e.g., DZLM, 2015), which produces a more holistic view. The study's framework refers to Kuntze (2012). Thus, a combination of cognitive (PCK) and affective aspects (PCB) is assumed. Additionally, self-oriented beliefs are considered in the context of PCB, since in this way a holistic base to describe changes of knowledge by taking part in a LTL is given.

Research on individual *problems in learning mathematics* covers a large range: Beyond approaches that describe such problems as a social construct, or approaches focusing on learning difficulties or disabilities in a narrower sense (for a survey: Scherer, Beswick, DeBlois, Healy, & Moser Opitz, 2016), different approaches focus on previously low achievements (e.g., Watson & De Geest, 2012). The perspective mentioned last mostly concentrates on arithmetic and in this context on typical phenomena such as rigidified counting (and a unilateral ordinal understanding of numbers) and an insufficient understanding of mathematical operations or the place value system (for surveys: Benölken, 2016; Denvir & Brown 1986). Mostly, a group of children is addressed which can be supported within a school's infrastructure, i.e., which does not show learning difficulties in the outlined narrower sense. As to identification or support, recent research independent of certain approaches demands a holistic view considering both cognitive and co-cognitive parameters (e.g., Nolte, 2009). Against the background of student teachers' education, the theoretical framework of both the LTL and, thus, the study corresponds to different aspects of the above outlined approaches: As to problems in learning mathematics, low attainments in arithmetic are focused on considering both typical phenomena and a holistic view in the identification and support procedures.

As to the development of PCK, practical situations that demand, e.g., scaffolding skills are assumed to be adequate opportunities of extending knowledge (Prediger, 2010). Existing findings indicate that one-to-one-interactions of a student teacher and a child might be a promising organizational form (e.g., Kilic, 2015). Against this background, "*learning-teaching-laboratories*" aim at a mutual growth and practical application of knowledge by a specific form of academic studies combining three dimensions: First, the support of children regarding a certain topic; then, the education of student teachers in this context, e.g., as to diagnostics and support; third, research aims like theory

building in the content focused on (Roth, Lengnink, & Brüning, 2016). Recent research mainly concentrates on a clarification of LTL-types and on an interdisciplinary consensus about defining the term of LTL. An example is given by the following definition:

LTL define a specific form of organization as to student teachers' academic studies combining children's learning with student teachers' professional development in a holistic way. In contrast to, e.g., standard lectures, seminars or practice lessons, LTL offer student teachers opportunities to develop, to enhance and to apply iteratively various skills of diagnostics, support and, thus, both teachers' professional acting and knowledge with regard to specific focuses in authentic, but complexity-reduced learning situations. (Brüning, 2016, p. 1274; translated by the author)

Hence, LTL include aspects and influences that are considered as most important by approaches on teachers' professional growth like the individuality of their learning in mutual reflection and enactment processes (e.g., Clarke & Hollingsworth, 2002). Even if LTL are conducted at more and more German universities in different "STEM"-disciplines, ongoing studies still focus on their evaluation. First impressions indicate that LTL are highly valued by student teachers and they are suited to ensure a sustainable growth of their knowledge about the respective topic (e.g., Brüning, 2016). The study's framework refers to Brüning's definition. Its cornerstones are transferred to the context of ISLA. The demanded complexity-reduction is realized by one-to-one-interactions.

Survey of a LTL-concept in the context of ISLA

The presented study is part of the long-term project "MaKosi" that focuses on the conception and evaluation of a professional development program connecting ISLA- and LTL-approaches (for details: Benölken, 2016). Summarized, the aims are the support of children low attaining in arithmetic and the development of student teachers' knowledge of ISLA. The student teachers' education is organized as a combination of a theoretical course and a project seminar with children. The theoretical course covers information about approaches in the field of problems in learning mathematics as well as concepts of diagnostics and support. While the theoretical course is a regular seminar at university, the project seminar takes place at a primary school once a week about 15 times per semester. Against the outlined framework of ISLA, diagnostics triangulate different tools: In a first step, teachers are given information about the framework and they elect children providing a justification in written form. Then, parents have to fill in a declaration of consent. In a second step, children, student teachers and scientists come together to get to know each other in a playful first session. In a third step, process-diagnostics follow considering both cognitive and co-cognitive parameters; mostly, non-standardized tools such as observations on children's task solving using rating sheets or guided interviews with children, teachers or parents are applied. Every project seminar session is divided into three parts: First, a preparing workshop where student teachers and scientists come together for 15 minutes in order to highlight specific aspects of observation or other determining factors; second, a 90-minute-children-session; finally, a reflecting 75-minute-workshop, in which each child's problems and possibilities as to an appropriate support are discussed. Within this schedule, the children's session is divided into three stages: In the beginning, a playful problem task is offered avoiding arithmetic contents to provide an adequate imagination of mathematics or to support both a positive self-perception of mathematical abilities and joy of problem solving (for example, the problem of "a ferryman, a wolf, a sheep and a head of cabbage").

At this stage, children can organize themselves considering ideas of a natural differentiation. Subsequently, one student teacher and one child turn into one-to-one-interactions of diagnostics and support in established teams for 60 minutes. Thus, the student teachers can develop, e.g., scaffolding abilities in a complexity-reduced situation. Tasks and activities applied in this context are taken from well-proven examples of literature (for examples see: Benölken, 2016), which the student teachers got to know in the theoretical course. They develop suggestions on both their compilation and detailed planning which are discussed during the reflecting workshop with all participating student teachers and the supervising scientists in order to ensure sustainable conducts. Each session closes with a game to support the children's joy of participating in the LTL.

The study

The study focuses on the *question* how student teachers' knowledge of ISLA develops by taking part in an ISLA-LTL. The *participants* were 25 primary student teachers; 11 (10 females, 1 male) took part in the winter semester 2015/2016, and 14 (only females) in the summer semester 2016. Mostly, they were in their third year of undergraduate studies. The study's character is explorative, i.e., generalizations were not intended, but existential propositions (Lamnek, 2010) about possible developments of knowledge by participating in the LTL. Thus, a qualitative *design* was advisable. As to the *method*, qualitative data were generated according to Rott (2017) by applying learning maps in a pre-post-comparison which were anonymized by codes to ensure unbiased interpretations. In the head, the student teachers were given the impulse to craft their way between their current status and their future work at schools: "Dealing with low attainments will be a challenge as to your work as a teacher, especially due to the knowledge of identification and support: What does this mean to you personally? Which way have you covered or which way will you have to cover in the future? Please lay out your way." (translated from German) All participants designed the maps for the first time, and they had to do it before taking part in the LTL at the beginning of a semester, and, again, at its end. As to the *analysis*, the pre- and post-maps were compared by a reconstructive pedagogic-iconological image interpretation, which becomes more and more accepted in different scientific disciplines. Its characteristic steps were observed: (1) Discussion of previous history and selection of key images, (2) image description and analysis (with regard to the factual, expressive and form-related sense), (3) context analysis, and (4) comparative analysis (Schulze, 2013). Data were interpreted within two meetings at the end of the summer semester 2016: The 14 participants analyzed in groups of two or three at least one, but for the most part two pairs of maps. Afterwards, the results were presented, and major observations were discussed in a plenary session.

Results

As to *key images*, their *description* and *analysis*, three types were identified: (1) An interrupted path, (2) a continuous path, and (3) a system of paths. The first type was found only within the pre-, the third one only within the post-, but the second type within both the pre- and post-drawings. Subsequently, we focus on the reconstructions of the examples shown by the Figures 1 and 2, which were conducted in the group meetings mentioned above and which reflect typical main features.

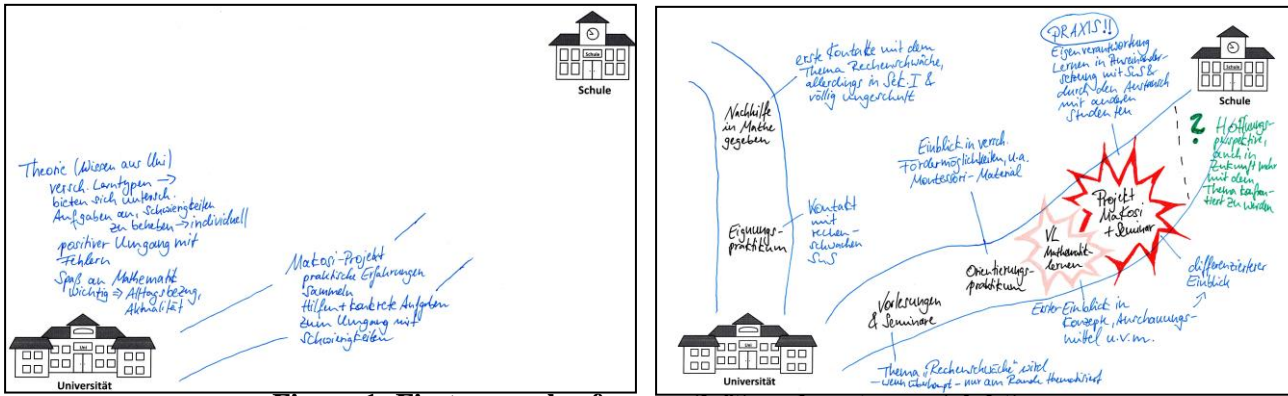


Figure 1: First example of a pre- (left) and post-map (right)

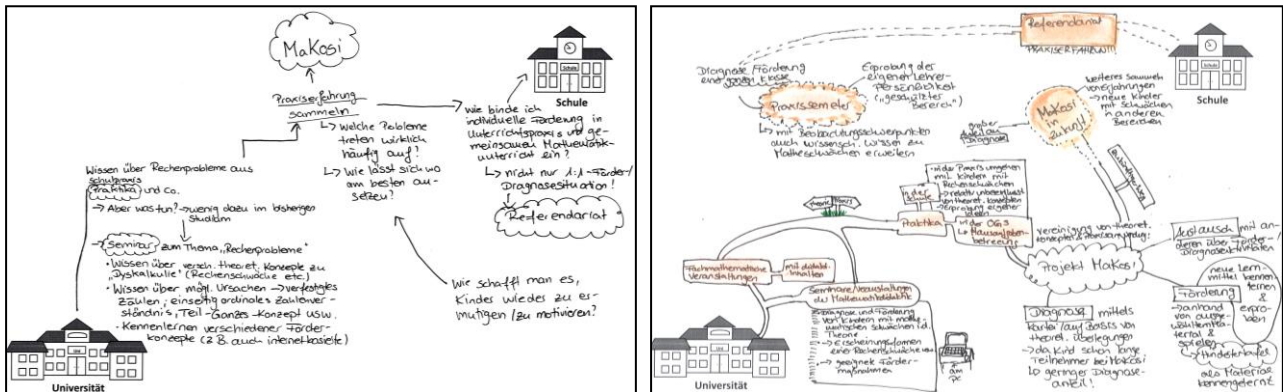


Figure 2: Second example of a pre- (left) and post-map (right)

As to the factual sense of the first example's pre-map (Figure 1, left), a lack of details is obvious, which might reflect that the creator is unfamiliar with the context. The expressive sense is characterized by monotony as to, e.g., colors, which might indicate the creator's uncertainty. Regarding the sense of form, the interrupted way seems to reflect that the creator cannot (yet) imagine how to achieve the purpose. As to the factual sense, the post-map (Figure 1, right) contains more details: Different remarks are phrased; thus, the creator seems to connect many thoughts to the path. Merged stars seem to reflect interdependent experiences that influenced the creator positively, but a question mark seems to indicate obscurity about future requirements. The expressive sense is characterized by a use of different colors highlighting the significance of the experiences' connection, for instance. As to the sense of form, the continuous path obviously reflects that the creator now perceives a way to achieve the purpose, even if it is flanked by the question mark. The path precedes the current status; thus, the creator seems to have developed a more holistic view on the way he or she passed. As to the factual sense of the second example's pre-map (Figure 2, left), a main feature is a wide range of remarks, which seems to reflect that the creator already connects several aspects to the path. An important detail is the remarks' phrasing in the form of questions in most of the cases; thus, the creator rather seems to ascribe uncertainty or just a small level of recognition to him- or herself. Moreover, clouds seem to emphasize particular past and future experiences. The expressive sense is rather monotonous, e.g., as to the coloring, which might indicate that the creator refers to a matter-of-fact way. Regarding the sense of form, the continuous path is drawn as a stairway; thus, the creator obviously distinguishes different steps of his or her knowledge's complexity. Arrows emphasize secondary objects, which might reflect that the creator at least considers different complex patterns. As to the factual sense of the post-map (Figure 2, right), a wide range of remarks still can be observed, but now they are put forward in the form of declarative sentences. Signposts seem to describe possible intentions and their connections. Clouds

and boxes seem to highlight important (mostly past) theoretical and (especially future) practical experiences. A computer seems to indicate an intertwining of the regarded focus with other domains. Finally, sections which the creator already had passed are characterized by continuous, but future sections by dotted lines. The expressive sense is characterized by different colors which underline the significance of main experiences; overall, a great confidence seems to be reflected. Aspects related to the sense of form confirm this impression: In contrast to the circle drawn in the first section of the map, the path continues afterwards directly, but winding to school, flanked by some concrete imaginations. The final part of the path system is drawn slightly broader compared to previous sections which might reflect that the creator will feel well prepared to enter school. In the creator's view, practical work seems to bridge impressions of running in a circle within theoretical studies, which are not connected directly to work at school, and achieving the objective, which is supposed to be a complex, but positive and manageable challenge.

As to a *context analysis* of the first example, the interrupted way of the pre-map (Figure 1, left) seems to reflect that knowledge on ISLA is assessed to be nonexistent or at least superficial by the creator (PCK), and he or she cannot imagine how to cope with ISLA at school (PCB). Comparing the post-map (Figure 1, right) indicates that the creator now reflects to have knowledge on ISLA (PCK), and that he or she perceives ways of handling ISLA at school (PCB). This impression is confirmed by concrete aspects and intentions given by the detailed remarks (e.g., top right, “self-responsibility”, “perspective of hope to face the topic in the future”), which were missing in the pre-map, and by elements like stars or colors, which underline the significance of taking part in the LTL as to developing knowledge of ISLA and, thus, of bridging theoretical knowledge and practical work. Regarding the second example, the continuous path shown by the pre-map (Figure 2, left) indicates that the creator already knows about some aspects of ISLA, even if this knowledge seems to be rather superficial (PCK) and he or she seems to be rather uncertain (PCB). Comparing this with the post-map (Figure 2, right) suggests that the complexity of the system of paths reflects an increase of knowledge (PCK), and the creator can well imagine to cope with ISLA at school (PCB). Questions posed in the pre-map (e.g., on the first step, “What has to be done?”) turned to concrete intentions and planning steps (e.g., top left, an intention as to the practical semester of academic studies “Enriching scientific knowledge by specific focuses of observation.”); particular attention is given to emphasize the significance of practical experiences, like taking part in the LTL, as to developing knowledge of ISLA and as to intertwining theoretical knowledge and practice.

Based on these examples, a *comparative analysis* of all pre- and post-maps suggests that both the student teachers' ways and their location on the ways changed. Their PCK of ISLA developed to more profound patterns, and their PCB to more confident characteristics. Put more precisely, the comparisons indicate mainly the following typical changes: As to cognitive aspects, before taking part in the LTL the student teachers' knowledge about ISLA seemed to be rather fragmentary and superficial for the most part. Moreover, most of them seemed to equate problems in learning mathematics unilaterally with learning difficulties in a narrower sense. In contrast, after participating in the LTL, the student teachers developed a complex knowledge of the entire field: They distinguished different approaches and considered phenomenology-related issues. Regarding affective aspects, before taking part in the LTL, the student teachers rather seemed to express uncertainty as to dealing with ISLA, which seems to reflect disadvantageous characteristics of self-efficacy. In contrast, after participating in the LTL, the maps indicate more proactive views: The

student teachers declared more complex perceptions of problems in learning mathematics, in particular as to a child's individuality, and they proposed precise plans to develop their knowledge. Moreover, they seemed to connect ISLA closer to teachers' responsibilities, and emphasized the significance of practice as to the development of aspects such as self-efficacy. Finally, as indicated by the discussed examples, there seem to be different types: A first one representing an "optimistic novice" (Figure 1), and a second one representing an "expectant expert" (Figure 2).

Discussion

The results indicate that participating in an ISLA-LTL and, therefore, an intertwining of theory and practice contributes sustainably to a positive development of both student teacher's knowledge about ISLA and their abilities to analyze children's thinking and learning in mathematics. This observation is in line with reports emphasizing the benefits of practical work with children as to the development of knowledge, and one main reason for this might be seen in the student teachers' constructivist learning (Sowder, 2007). Thus, beyond the context of ISLA, the results suggest the hypothesis that LTL provide an appropriate professional development program for student teachers to develop their abilities in analyses of children's thinking and learning. Of course, the study's character is explorative, and it has obvious limitations; for instance, the reconstructions as to interpreting the use of colors (or, e.g., their absence) were conducted within a group, but it remains uncertain, if a consensus view is the right one (Lamnek, 2010). Subsequent research might focus on a deeper clarification as to evaluations of ISLA-LTL, and as to the benefits of LTL in general; in particular, different LTL-focuses like support of mathematics interest should be taken into account.

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