Characteristics of out-of-field teaching: Teacher beliefs and competencies

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In recent years, some efforts have been made to consolidate out-of-field-teaching as research field in mathematics education. Taking teachers' professional knowledge as reference frame, out-of-field-teachers seem less qualified regarding CK and PCK in mathematics than teachers that were especially trained to teach their subject. In this paper, we approach the phenomenon of out-of-field-teaching by focusing on both teachers' beliefs and competencies while the latter is operationalized as skills in designing mathematical tasks for written exams. Data was collected throughout a qualification program particularly focusing on out-of-field-teachers' domain-specific professional knowledge. We discuss in detail design aspects of our on-going research and give first insights into the changes of out-of-field-teachers' beliefs reflecting their professional development in the course of the qualification program.

Keywords: Out-of-field-teaching, beliefs, competencies, CPD.

INTRODUCTION

Current developments in mathematics education show an interesting phenomenon: A considerable body of mathematics lessons is taught by teachers who have not been qualified as mathematics teachers through certified courses of studies at university (cf. Törner & Törner, 2010). In the following, we refer to this heterogeneous group of teachers by using the term "out-of-field". Due to a thin research base, there are barely information about the range of this phenomenon which strongly varies across different countries, educational systems and school types. In the U.S. for instance some efforts by Ingersoll (1999) have been made to estimate the amount of out-of-field-teaching in a large-scale study which reveals that up to one third of all high school mathematics teachers do not hold a teaching certificate in mathematics. For Germany, Törner and Törner (2010) state that almost 80% of primary mathematics lessons are taught by teachers who have not taken any mathematics courses during their professional education. Although, in higher education the average percentage of out-of-field-teachers in mathematics education decreases, it still remains on an estimated level of 15% referring to lower secondary grades (cf. Bosse & Törner, 2013). Against this backdrop, the issue of out-of-field-teaching is *undertheorized* and *underresearched* in reference to crucial aspects that characterize out-of-field-teachers' professional knowledge and practices. Within this contribution, we discuss an initial approach to address this lack of research.

Considering out-of-field-teaching in the light of models of teachers' professional competencies (cf. Blömeke, Suhl, & Döhrmann, 2012) we encounter a twofold problematic scenario: Due to missing courses of studies it can be assumed that – put carefully – out-of-field-teachers are faced with considerable knowledge-gaps concerning different facets of their professional competence. These gaps in turn affect their capability to act effectively in the classroom, to provide high quality mathematics lessons, and to support sustainably students' performances (Richter, Kuhl, Haag, & Pant, 2013). In our study, we thus put emphasis on key-aspects of out-of-field teachers' professional knowledge to understand which categories are decisive for describing their specific situation. Reflecting on research about out-of-field-teachers' professional identity we additionally focus on teachers' beliefs about mathematics and the teaching and learning of mathematics, as these are crucial parameters considering teachers' decision-making and lesson practice (cf. Bosse & Törner, 2012; Hobbs, 2012). In our study we address this aspect by focusing on out-of-filed-teachers' skills to design mathematical tasks for written exams. In sum, we will consider the issue of out-of-field-teaching from two perspectives:

(1) First, we outline some key aspects of the *theoretical* foundations, in particular on mathematics-related beliefs and on designing mathematical tasks as one crucial aspect of teachers' competencies.

(2) Second, we discuss in detail our *methodological* approach using mixed methods to capture teachers' beliefs and their competencies, displayed by designing mathematical tasks. As core element of this perspective we describe and validate a category system which has been developed to characterize out-of-field-teachers' decisions while choosing mathematical tasks for class assessment.

In this paper, we give preliminary results of our on-going research while accompanying a group of out-of-field teachers throughout a one-year qualification program.

THE ROLE OF BELIEFS AND COMPETENCIES

Teachers' professional knowledge has been researched in depth and from various perspectives considering both cognitive and affective-motivational aspects (cf., Shulman, 1986). Drawing on key findings of these studies teachers' professional knowledge is conceptualised as interplay of *Content Knowledge (CK), Pedagogical Content Knowledge (PCK), General Pedagogical Knowledge (PK), professional motivation, beliefs* and *self-regulation*. Large-scale empirical studies capture the interplay of these cognitive facets and affective-motivational characteristics and underpin efforts to capture classroom practices with regard to both dimensions (cf. Blömeke et al., 2012). Ball and Bass (2000) further work on a domain-specific conceptualization when focussing on mathematical knowledge needed for teaching. They elaborate on teachers' knowledge of mathematics as the decisive parameter for improving their instructional quality. One promising attempt to conceptualize teachers' professional knowledge from a more situative perspective is provided by Lindmeier and colleagues (2013). In particular, she stresses that a subject-specific model for teacher cognition encompasses three components: *basic knowledge* (CK, PCK), and the two complementary components *reflective competences* and *action-related competences*. In particular, the action-related competencies comprise the abilities needed to perform in the classroom. What is more, Lindmeier and colleagues (2013) stress that for both reflective and action-related components, basic knowledge plays a key role for enactment.

Considering in addition the role of teachers' beliefs, one can conclude that these play a key role for decision-making in the classroom (Törner, Rolka, Roesken, & Sriraman, 2010). Our research refers to the dimensions of beliefs presented by Grigutsch, Raatz, & Törner (1988): *beliefs about the nature of mathematics*, *the teaching and learning of mathematics* and *students' mathematics achievement*. Beliefs are often robust and therefore difficult to change or as Sowder (2007) puts it "many of teachers' core beliefs need to be challenged before change can occur" (p. 160). What this quotation stresses is that any change or development in teachers' beliefs is a long-term process. Accordingly, Toerner, Rolka, Roesken and Schoenfeld (2006) analyse the teaching practice of an experienced teacher after having participated in an in-service training course on using open-ended task in mathematics teaching. Since it was not the focus of the study to examine the effectiveness of the professional development event, it turned out that the teacher's beliefs built a hindrance to successfully implementing new ideas. Nevertheless, other studies report about quick changes in beliefs while teachers participated in a professional development program.

DZLM QUALIFICATION PROGRAM: PROFFUNT

The German Centre of Mathematics Education offers various qualification programs and training courses for multipliers and out-of-field-teachers in order to foster their *Continuous Professional Development* (CPD). The project ProFFunt1 is a certification course especially designed to support out-of-field teachers in lower secondary school, and is a collaborative project of the Universität des Saarlandes, of the Landesinstitut für Pädagogik und Medien of the Federal State of Saarland and the DZLM. The course has lasted one year, and addressed teaching in grade five and six, and will be extended to grades seven and eight in the next year. ProFFunt draws on the success-

1 ProFFunt = „Professionalisierung fachfremd Unterrichtender"

ful KOSINUS program2 that so far has reached more than half of the respective schools in the Saarland. Support for teachers for probing issues in practice is provided by the chair of mathematics and its didactics.

The ProFFunt project especially focuses on the development of out-of-field teachers' competencies which are considered as being decisive in regards of teachers' professional knowledge (cf. Blömeke et al., 2012). The content was developed throughout analyses based on *Stoffdidaktik* including relevant mathematics topics in grade five and six such as algebra, geometry and basic ideas in stochastics. Throughout the ProFFunt project teachers additionally received a profound overview on PCK issues and were supported in implementing these aspects into their teaching, ranging from task design to planning of teaching sequences. Teachers were required to participate in teams of two (tandem) in order to foster collaboration in their respective school. Furthermore, the course consisted of six modules with a total workload of 200 hours. ProFFunt follows a so-called *sandwich-structure* with alternating theoretical and practical phases in which the participants experience a combination of learning, implementation and reflecting phases, comprising also e-learning and working on a portfolio. The intention of this structural design is to foster long-term changes in teachers' views on mathematics learning and to enable sustainable competence development. In this regard, it appears promising to stress teachers' beliefs and action related-competencies, as these are long-term developing aspects of teachers' professional knowledge.

2 http://didaktik-der-mathematik.de/pdf/gdm-mitteilungen-90.pdf, http://www.saarland.de/114409.htm

RESEARCH ON PROFFUNT

A broad research plan has been developed in order to cover various aspects of out-of-field teachers' professional knowledge. The research design acknowledges the researchers are not involved in conducting the course and that out-of-field teachers' development should not be bothered by intensive testing. An overview on the research design is given in Figure 1 and is briefly explained hereafter.

Our approach is twofold and addresses teachers' beliefs and competencies: On the first level we focus on out-of-field-teachers' development of beliefs throughout the qualification program. On the second level we scrutinize teachers' competencies in designing mathematical tasks for written exams. Both constructs are investigated in a pre-post-comparison design referring to the period before and after the ProFFunt course. In addition, we evaluate our results in view of a control group of teachers who studied mathematics as a school subject at university so that we are able to describe and understand crucial differences between *in-field* and out-of-field-teachers. Finally, the connection between out-of-field teachers' beliefs and the way of designing mathematical tasks before and after the qualification program is considered in order to check for correlation between these two categories (Figure 1). In particular we focus on the following research questions:

a) What categories do out-of-field-teachers consider in designing mathematical tasks for written exams? What influence has a one-year qualification program on the development out-of-field of teachers' competencies in designing tasks?

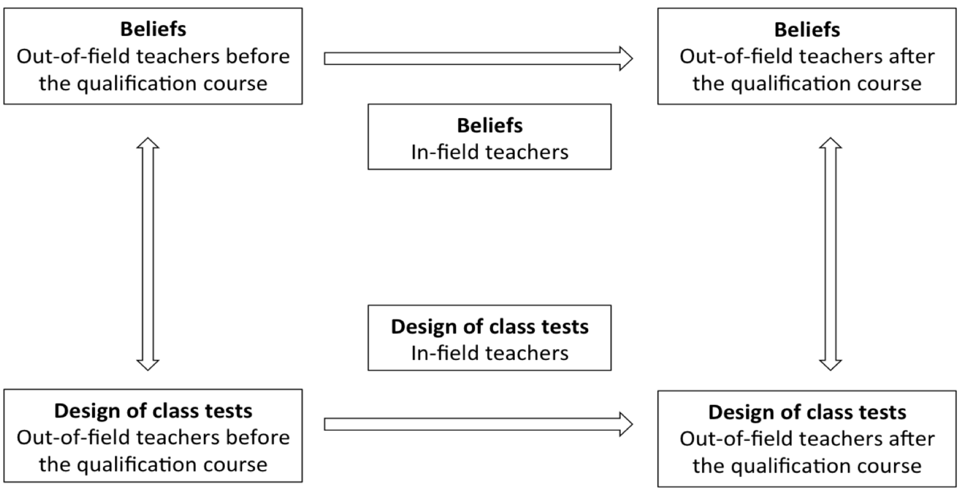

Figure 1: Overview on the research plan

b) What mathematics-related beliefs do out-of-field-teachers possess? What influence has a one-year qualification program on the development of out-of-field teachers' beliefs?

c) What differences between out-of-field-teachers and in-field teachers could be detected with reference to both constructs beliefs and action-related competencies?

In this paper, we do not fully answer our research questions, but outline our research design, carefully describe our instruments and present preliminary results.

METHOD

In the one-year ProFFunt course, 13 out-of-field-teachers participated, representing a highly heterogeneous group of teachers which non-mathematics educational practice varies from less than 5 years to up to 15 years. Working as a teacher within the educational system in Germany requires studies in CK and PCK in at least two different subjects complemented by pedagogical courses. Hence, participants of our study have a considerable body of previous knowledge concerning pedagogical aspects like for example learning theories and implementation strategies, but established in a different context than mathematics. Combined with the fact that the participants' knowledge differs in the specific subjects they have studied, these circumstances increase the heterogeneity of the sample and makes working with the group of out-of-field-teachers in terms of CPD-training and research challenging. As a control group we refer to data raised within the scope of the MT21 research program (Blömeke, Kaiser, & Lehmann, 2008), where prospective and in-service teachers (N=139) who studied mathematics at university participated.

Data was collected through combining qualitative and quantitative methods to capture the complexity of out-of-field-teachers' specific situation. Their mathematics-related beliefs have been revealed by using a questionnaire which has been developed and validated in the scope of the TEDS-M study (cf. Blömeke, Suhl, & Kaiser, 2011). This instrument displays a shortened and slightly modified version of the items originally developed by Grigutsch and colleagues (1988). The questionnaire was distributed to the participants before and after the DZLM qualification program. The questionnaire consists of 33 items that are rated on a six-point Likert-Scale, ranging from strongly disagree to strongly agree. Considering various aspects of teachers' beliefs the instrument encompasses the following five subscales: *nature of mathematics as rules and procedures* (6 items), *nature of mathematics as process of inquiry* (5 items), *learning mathematics through teacher direction* (8 items), *learning mathematics through active learning* (6 items) and *mathematic achievement as fixed ability* (8 items). A short excerpt from this questionnaire is shown in Figure 2. Applying the TEDS-M belief questionnaire ensures a stable instrument with sufficient scale reliability.

Focusing on designing mathematical tasks for written exams as a core aspect of teachers' action-related competencies, we developed a category system which refers to key findings from current research in mathematics education. Throughout the qualification program, participants of our study were asked to allocate and provide the written exams they delivered in grade five. Concerning content, the written exams mainly focussed on arithmetic and geometry in grade 5. As a result of this procedure we are able to gain theory-based insights into crucial aspects of out-of-field-teachers' professional knowledge. In the developmental process of the category system we brought together various findings from research

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
Mathematics is a collection of rules and procedures that prescribe how to solve a problem.	☐	☐	☐	☐	☐	☐
In mathematics many things can be discovered and tried out by oneself.	☐	☐	☐	☐	☐	☐

Figure 2: Exemplary items of the belief questionnaire

on mathematics education and pedagogical theory concerning learning and achievement through tasks. The instrument consists of four domains reflecting key-aspects of teachers' professional knowledge:

(OCS): *Orientation toward task-related competencies and educational standards*,

(OPK): *Orientation towards task-related PCK*

(OCP): *Orientation towards task-related cognitive processes*

(ODC): *Orientation towards task-related difficulty and complexity*

For the sake of brevity, we do not discuss every domain in detail, and limit ourselves to shortly describing our methodical procedure for analysing mathematical tasks. In the first domain (OCS) we focus on three categories referring to the learning standards in mathematics education in Germany (cf. Blum, 2006). In particular, we regard the design of a task from the perspective of content-related and process-related competences. An example of categories used in the domain OCS is shown in Figure 3. Categories located in OPK deal with key aspects of pedagogical content knowledge in mathematics. In the context of our research, we choose 4 categories in this domain: First, we take a look on how the structure of the task motivates students' learning processes (cf. Bruder et al., 2008), second we concentrate on which strategies in designing a task are used to foster students' active engagement in a comprehensive learning process (cf. Büchter & Leuders, 2005). While the third category in this domain emphasises the form of representation, the fourth category considers linguistic aspects of the task (cf. Meyer & Prediger, 2012). Reflecting on students' cognitive processes working on a mathematical task in the domain OCP, we include categories dealing with Blooms taxonomy of learning domains (cf. Bloom, 1976) to cover a more pedagogical perspective. The second category in this domain deals with the question what level of mathematics-related cognitive processes like generalising or using formal and abstract expressions are required for solving the task (cf. Cohors-Fresenborg, Sjuts, & Sommer, 2004). In the last domain ODC we include several complementary categories covering key aspects of difficulty and complexity of a mathematical task (cf. Bruder et al., 2008). In particular we focus on students' required time to solve the task, amount of steps to provide a correct solution, the response format, and finally mathematical correctness.

Three experts in mathematics education from our research team independently used the developed category system to analyse 10 exams (60 tasks) in order to check the quality and sensitivity of our instrument. The degree of agreement was calculated by estimating the inter-rater reliability in terms of Cohen's kappa for each category. In regard of the constructed instrument we estimated Cohen's kappa between 0.72 and 0.95 for tasks which shows satisfying agreement (Hallgren, 2012).

PRELIMINARY RESULTS AND DISCUSSION

Reflecting on our broad research plan, we will limit ourselves to preliminary results respecting the development of out-of-field-teachers' beliefs before and after participating in the ProFFunt course, in comparison to a group of "in-field" mathematics teachers. In addition, we would like to stress several aspects of our research questions, to draw some conclusions concerning our methodical approach and to anticipate expectable results of our on-going research process.

First, we concentrate on the results derived by the TEDS-M beliefs questionnaire. An overview showing means and standard deviation of out-of-field teachers' beliefs on the five subcategories before and after

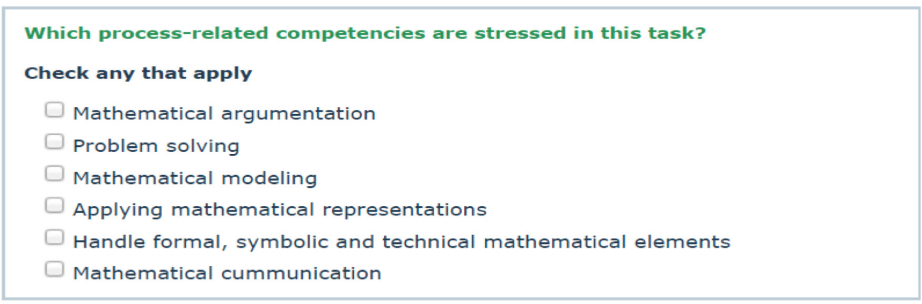

Figure 3: Exemplary item of the domain OCS of the category system

participating in the qualification program is given in Table 1. Considering beliefs about the nature of mathematics it becomes apparent that the participants are strongly oriented towards the *nature of mathematics as process of inquiry* at the beginning and even more at the end of the ProFFunt course, showing a small effect size. On the contrary the *nature of mathematics as rules and procedures* is rated less frequently before the course and decreases afterwards, showing a medium effect size. With reference to the beliefs about learning mathematics we can find that out-of-field-teachers in this study before and after the ProFFunt course lay a strong emphasis on *learning mathematics through active learning* whereas *learning mathematics through teacher direction* is considered minor relevant. In addition, *mathematics achievement as fixed ability* is rated low before and after the qualification program. Our results support the assumed changeability of out-of-field teachers' mathematics-related beliefs after participating in a qualification program.

In comparison to the sample of "in-field" teachers derived from the MT21 study, the group of out-of-field teachers in ProFFunt shows minor differences when it comes to their mathematics-related beliefs (Table 2). Out-of-field teachers consider *mathematics learning through teacher direction* as minor relevant compared to "in-field" teachers.

These findings show an interesting phenomenon: Despite the fact, that being out-of-field in most cases comes along with considerable knowledge gaps in CK and PCK, participants in this study strongly emphasize mathematics' dynamic character and its potential as source of effective and active learning opportunities at the start of the qualification program. These results are remarkable because they contradict the popular assumptions that out-of-field-teachers feel less competent in mathematics and teaching mathematics and therefore preferably refer to structures, rules and procedures. We take these surprising aspects in our findings to contemplate on one essential issue: Who are we talking about when labelling

Dimension of beliefs		pre	post	effect size
Nature of mathematics as rules and procedures	Mean StD	3.8 .81	3.4 .89	-0.29
Nature of mathematics as process of inquiry	Mean StD	5.0 .43	5.3 .61	0.11
Learning mathematics through teacher direction	Mean StD	2.4 .75	2.5 .68	0.05
Learning mathematics through active learning	Mean StD	5.1 .49	5.2 .60	0.01
Mathematic achievement as fixed ability	Mean StD	2.5 .70	2.5 .82	-0.08

Table 1: Out-of-field-teachers beliefs before and after the qualification program

Dimension of beliefs		Sample (n=11)	MT21-Germany (n=139)
Nature of mathematics as rules and procedures	Mean StD	4.0 .67	3.9 .98
Nature of mathematics as process of inquiry	Mean StD	5.1 .48	4.9 .87
Learning mathematics through teacher direction	Mean StD	2.4 .74	3.2 .88
Learning mathematics through active learning	Mean StD	5.2 .41	5.3 .71
Mathematic achievement as fixed ability	Mean StD	2.6 .68	2.2 .82

Table 2: Out-of-field-teachers and in-field-teachers mathematic-related beliefs

teachers as being “out-of-field”? What is missing is a concise definition who out-of-field teachers are and what out-of-field teaching is about. In the light of these thoughts our paper enables an innovative approach to characterize key aspects of out-of-field-teachers' professional knowledge on the basis of cognitive and affective competencies. In our further research we take up these findings and compare our results on out-of-field teachers' beliefs to their action-related competences. The category system described and validated in this paper provides a sustainable basis concerning the approach to characterize the issue of out-of-field-teaching more precise.

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