A protocol for analysing mathematics teacher educators' practices

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Studying practices in a teaching-learning environment, such as professional development programmes, is a complex and multi-faceted endeavour. While several frameworks exist to help researchers analyse teaching practices, none exist to analyse practices of those who organize professional development programmes, namely mathematics teacher educators. In this paper, based on theoretical as well as empirical results, we present a protocol for capturing different aspects of mathematics teacher educators' practices in a professional development setting. Implications for professional development programmes' planning, implementation and evaluations are given at the end of the paper.

Keywords: Mathematics teacher educators, professional development, training practices.

PROFESSIONAL DEVELOPERS OF MATHEMATICS TEACHERS

The teaching-learning quality in schools and, with it, teacher professionalisation has long been a concern of educational organisations, schools, governments and researchers and continues to grow in importance. Many countries, such as England (National Centre for Excellence in the Teaching of Mathematics (NCETM)), Sweden (National Centre for Mathematics Education), Austria (Austrian Centre for Instructional and School Development), set their focus to improve education, and in that effort, are investing vast resources in teacher professional development. These countries established so called CPD institutions, which offer a systematic approach to large scale and sustainable CPD, establishing standards for high quality CPDs. This has been recognised as one driving force to allow reform of school mathematics. Germany is not an exception to this phenomenon. For years already, the German educational system is being challenged with many difficulties, such as considerable shortage of specialised secondary subject teachers, high quota of at-risk students, more and more out-of-field teachers, and a high variability between different federal states (Kramer & Lange, 2014). In 2010, the German Center for Mathematics Teacher Education (DZLM) was founded as a cooperation of seven universities, and is oriented at improving and innovating the German mathematics classroom. The core objectives of the centre are to promote continuous professional development, set nationwide standards for it, and develop quality needs-based CPD programmes.

However, do we have the capacity to reach plethora of mathematics teachers? Gal (2013) in his PME plenary talk in Kiel discussed this issue in a sense of *2.5% rule*. The 2.5% rule denotes the fact that only 2.5% of teachers are novice teachers coming from the university. Thus, this small group might receive "up to date" quality teaching and learning ideas as advocated by current professional organisations and new curricula. Gal further warned that, when we train as many inservice as preservice teachers, a quota of barely 5% can be achieved. This fact raises the need to develop new structures within the professional development institutions to reach the big masses. Along these ideas, DZLM's key mission is to develop comprehensive training programs to educate mathematics teacher educators (MTEs), sometimes shortly called "multipliers", as it would allow for a large scale dissemination of the centre's initiative. Depending on the country, MTEs take upon different roles (e.g., coach, mentor, specialist). They are responsible for strengthening classroom teachers' understanding of mathematics content, and helping teachers develop more effective mathematics teaching practices, and by doing that to better student learning. Hence, MTEs are central for providing opportunities for teachers' professional development.

Elliot and colleagues (2009) contend that this area has been understudied – we know very little as to what MTEs need to know and be able to do – but is growing in its importance (e.g., Kuzle & Biehler, 2015; Rösken-Winter et al., 2015). Understanding MTE's practices is essential for attending their diverse needs – during planning, implementation, and evaluation of the professional development programmes. The more we know about how to support them, the more mathematics teachers can benefit. In order to fill in this gap, we present here a protocol for analysing MTEs' training practices, which was developed on the basis of effective CPD practices. We contend that such protocol may allow scholars with lenses for evaluating MTEs' PD courses and at the same time supporting their further development.

THEORETICAL CONSIDERATIONS WITH RESPECT TO EFFECTIVE CPD FACTORS

In this section, we give a succinct overview of descriptors for effective professional development from the literature (e.g., Cochran-Smith & Lytle, 1999; Garet et al., 2001; Lipowsky, 2004; Lipowsky & Rzejak, 2012; Putnam & Borko, 2000). These are elaborated by outlining DZLM's (2013) six PD design principles, which were used as a theoretical frame in this paper as well as in Kuzle and Biehler (2015). There is a small overlap between the two papers, however, without literal quoting.

Learner-orientation

Effective professional development links directly to teachers' job, namely teachers' curriculum, and their specific needs and concerns. In other words, the training courses focus on the individual, heterogeneous prerequisites and needs of the participants. They encourage and demand active and responsible participation of the participants in design and implementation of the PD. Hence, the participants are not informed, but involved as active learners in this process through which they develop their professional knowledge (Garet et al., 2001). However, PDs that are based solely on this knowledge do not suffice for influencing their actions. They need to, however, address the individual circumstances of the participants, account for participants' daily activities, and capitalise on teacher's prior knowledge and experiences. Ensuring and amplifying learner-orientation can be achieved through designing and administering preliminary inquiry regarding participants' experiences, expectations, and needs (Kuzle & Biehler, 2015).

Case-based learning

Relating CPD practices to the participant, his or her experiences, teaching and/or student learning supports teacher motivation and commitment to the learning process. In other words, the reference to teachers' everyday situations, so called "cases" or "training cases" serve both as a starting point and as a field of application for teaching and learning in the context of the PD. To intensify case-relatedness the MTEs can incorporate their student work or use participants' practical experiences (Kuzle & Biehler, 2015). In either case, subject-specific learning processes and learning outcomes of learners (e.g., pupils) should be diagnosed, interpreted, and direct consequences for the teaching practices should be extracted (e.g., Lipowsky & Rzejak, 2012; Timperley, 2011). Combining individual needs with overreaching goals of the professional development initiative, strengthens teacher commitment to the PD and increases motivation to learn (Timperley, 2011).

Competence development

Effective professional development is coherent; competence and goal orientation are a crucial prerequisite for a didactical and organisational design of PD that satisfy "depth and breadth of impact" (e.g., Garet et al., 2001; Lipowsky & Rzejak, 2012). This construct is multi-faceted and encompasses all resources teachers need to create quality teaching-learning environments. Among others, competence development should address teachers' professional knowledge, including also orientation towards students' learning (Lipowsky & Rzejak, 2012). This competence and goal orientation should be transparent for all concerned parties (Kuzle & Biehler, 2015). Only then can the references to one's own teaching practices become clear and the implementation tangible (Elliot et al., 2009).

Application of various instructional formats

To ensure interactive learning experiences, various instruction formats should be combined in collaboration with the leader(s) and other teachers. A diverse variety of working methods (e.g., blended learning seminars, practice- and collaborative based work, self-study) supports participants in their skill acquisition, and helps accommodate different learning styles and preferences. The participants must also be given time to engage in different activities at different levels and

in different settings in order to learn or consolidate their knowledge (Putnam & Borko, 2000). In addition, an intertwinement of input, active learning and reflection phases (so called "sandwich model") in crucial for connection between theory and practice.

Stimulating collaboration

Another essential CPD design aspect is to stimulate cooperation among the participants, and between the participants and the professional developer. This fosters exchange of experiences. Whereas using various instructional formats begins at fostering collaboration (short-term collaboration), these could be used as a starting point for a collaboration going beyond the CPD course itself (long-term collaboration). Thus, beyond just sharing ideas, and reflecting on the learning process, the participants, for instance, work together towards a common goal, jointly plan lesson, and organise mutual classroom visits (Lipowsky & Rzejak, 2012). In that manner, community building and networking can take place, which is together with professional developer-teacher structure, important for sustainability of PDs (Zehetmeier & Krainer, 2011). The extent of effect is dependent on the PD format.

Fostering (self-)reflection

Relevance of a PD and the sustainability of the professional learning can also be attained through reflective activities (Ingvarson, Meiers, & Beavis, 2005). Participants are encouraged to engage in collaborative and self-reflection on covered topics/material as well as on their own teaching, student work, attitudes, conceptions, and other. Through reflective practices the teachers can consolidate their skills and knowledge, and better understand teaching and learning in the classroom (e.g., Cochran-Smith & Lytle, 1999; Putnam & Borko, 2000). Reflective practices are most effective when reviewed throughout the PD (Ingvarson et al., 2005).

PROTOCOL FOR ANALYSING TRAINING PRACTICES

In the previous section and in Kuzle and Biehler (2015) we outlined effective professional development design principles. As seen above each design principle is composed of many different attributes. These were used to create a protocol for analysing what different attributes of each design principle can get implemented (see Table 1). In addition, we assigned to what extent these practices can be addressed in a PD with "yes", "no", and "partly".

This instrument was tested on a sample of PDs, that took place as a part of five month long DZLM's CPD "Competence-oriented teaching and learning of data analysis" for MTEs (Biehler, Kuzle, & Wassong, submitted; Kuzle & Biehler, 2015), which was developed by a team of researchers from the University of Paderborn (Biehler, Kuzle, Oesterhaus, Wassong). The CPD program focused on deepening MTEs' professional knowledge of teaching statistics using digital tools, and developing MTEs' competencies and knowledge for developing and implementing PD in statistics. As a part of that CPD, five MTEs' teams developed and implemented five 4-hour long PDs on teaching data analysis with statistical software. The general structure was prescribed by the course designers and was composed of 4 thematic blocks: (1) introductory block (ca. 1 hour), (2) block 1 (1¼ hours), (3) block 2 (1¼ hours), and (4) reflection and closure (ca. ½ hour). While the general function of the first and last block was clear, the mentors were free to organize and implement blocks 1 and 2, however, they had to select content and activities from the CPD for them and implement DZLM design principles. These were video-taped and then analysed using content method analysis as suggested by Miles and Huberman (1994).

For filling in the protocol, we used a five-step procedure for analysing the MTEs' practices exhibited in each PD. First we divided the first short PD into blocks. Secondly, for each block in the PD 1 we identified whether different design principles occurred at all. Thirdly, after having determined the six design principles and its accompanying attributes for each block, we looked at their quality in each block. For each block, we assigned the three categories, yes, partly, no, to each of the characteristic attributes for each design principle based on the following algorithm:

- A statement got categorised as "yes" when it was thoroughly and thoughtfully addressed within the block.
- A statement got categorised as "partly" when it was either not thoroughly or thoughtfully addressed within the block.
- A statement got categorised as "no" when it was not addressed whatsoever within the block.

DESIGN PRINCIPLES	Addressed level		
	Yes	Partly	No
Learner-orientation			
MTEs' focus of the PD is of relevance to MTs.			
MTE provides opportunities for MTs to share experiences with respect to the PD topic.			
MTE designs the PD in a manner that allows MTs to be integrated into the learning process as active learns through hands-on activities.			
MTE designs the PD in a manner that allows MTs to be integrated into the learning process as active learners through hands-on technology use.			
MTE provides MTs opportunities to actively build their content knowledge on the basis of their existing knowledge and experiences.			
MTE provides MTs opportunities to actively build their pedagogical content knowledge on the basis of their existing knowledge and experiences.			
MTE provides MTs opportunities to actively build their technological knowledge on the basis of their existing knowledge and experiences.			
MTE provides MTs with opportunities to actively build their technological pedagogical content knowledge on the basis of their existing knowledge and experiences.			
MTE provides MTs with opportunities to build an understanding of student's thinking in a specific area.			
Case-based learning			
PD connects to MTs' teaching practices.			
PD combines the MTs' needs with the goals of educational initiative.			
MTE integrates MTs' input with respect to the topic of the PD.			
MTE addresses explicitly specific needs and concerns of MTs with respect to their teaching experiences and daily concerns.			
MTE allows MTs to apply newly learned knowledge into follow-up activities.			
MTE allows MTs to discuss newly learned knowledge with respect to their teaching practices.			
The content of the PD is illustrated on real student work (artefacts).			
MTs analyse student work, interpret it and reflect on their student learning in their own classroom or in the classroom of other MTs.			
Competence development			
MTE's focus of the PD connects to specific curricula and learning standards.			
MTE has a well-defined image of effective classroom learning and teaching.			
MTE makes/describes clearly fostered competencies and/or goals are transparent.			
MTE focuses on developing MTs' content knowledge.			
MTE focuses on developing MTs' pedagogical content knowledge.			
MTE focuses on developing MTs' technological knowledge.			
MTE focuses on developing MTs' technological pedagogical content knowledge.			
MTE engages MTs as adult learners in the learning approaches.			
MTE models pedagogy and various instructional strategies for the whole sequence of lessons designed to support development of conceptual understanding.			
MTE provides MTs with concrete ideas for implementing new materials and/or ideas in own classroom.			
MTE supports MTs in understanding student thinking with respect to the topic.			
MTE emphasises how to improve student learning.			
MTE helps MTs anticipate possible student learning difficulties and/or misconceptions.			
Application of various instructional formats			
MTE accommodates individual learning styles and preferences.			

MTE engages MTs in different learning formats such as sharing and discussion, reflection, solving problems.			
In a PD, input, active learning and reflection phases are intertwined.			
MTE relates different parts of the PD one to another.			
Stimulating collaboration			
MTE provides MTs with opportunities to collaborate with other MTs (share ideas, viewpoints, work together).			
MTE supports MTs to develop their professional expertise and to serve in leadership roles.			
MTE supports MTs to plan together instruction and/or analyse student work with respect to a common goal.			
MTE offers MTs support beyond the PD course itself.			
Fostering (self-)reflection			
MTE provides MTs with opportunities to reflect throughout the PD.			
MTE provides MTs with opportunities to reflect critically on their teaching practices.			
MTE provides MTs with opportunities to reflect critically on the new ideas particularly with regards to their teaching practices, and experiences.			

Table 1: Protocol for analysing MTEs' training practices

In the fourth step, on the basis of step 3 we assigned the three categories, yes, partly, no, to each of the characteristic attributes for each design principle for the PD as a whole. The categorisation was based on the following algorithm:

- A statement got categorised as "yes" when it was overall always or not once thoroughly and thoughtfully addressed (2 points).
- A statement got categorised as "no" when it was never addressed (0 points).
- A statement got categorised as "partly" for all other cases (1 point).

Lastly, we visualised a profile of the PD in a table (see Table 2) on the basis of the sum of the scores of characteristic attributes for each design principle. This process was used for all other short PDs. In addition, Table 2 allows for insights what design principles were more prevalent, and how the PDs differed in their focus and goals.

In addition, another rater coded the data. We checked the inter-rater reliability by using the formula recommended by Miles and Hubermann (1994), in which the coder reliability is calculated in the following manner: coder reliability = number of agreements/total number of agreements + disagreements. The inter-rater reliability was calculated at 96.6%.

DISCUSSION: A 4-DIMENSIONAL MODEL OF TRAINING PRACTICES

Reform of mathematics classroom is an ambitious and very much needed cause. Understanding MTEs' practices is an essential mean to achieving this goal.

PD	Design principles					
	Learner -orientation	Case-based learning	Competence development	Application of various instructional formats	Stimulating collaboration	Fostering (self-) reflection
PD 1	13 (72.2%)	10 (62.5%)	17 (65.4%)	8 (100%)	4 (50%)	6 (100%)
PD 2	9 (50%)	5 (31.3%)	12 (46.2%)	6 (75%)	3 (37.5%)	1 (16.7%)
PD 3	16 (88.9%)	15 (93.8%)	23 (88.5%)	8 (100%)	5 (62.5%)	5 (83.3%)
PD 4	10 (55.6%)	4 (25%)	10 (38.5%)	6 (75%)	2 (25%)	1 (16.7%)
PD 5	11 (61.1%)	7 (43.8%)	15 (57.7%)	5 (62.5%)	4 (50%)	2 (33.3%)
Total	18 (100%)	16 (100%)	26 (100%)	8 (100%)	8 (100%)	6 (100%)

Table 2: Descriptive statistics of protocols for analysing MTEs' practices

The developed protocol for analysing MTEs' practices proved to be a reliable instrument for measuring what different effective CPD design principles and to which extent these got implemented in the PD courses. More particularly, the above presented protocol offers means to evaluating MTEs' PD practices with respect to effective CPD factors. Hence, it offers lenses for insights into their training practices and challenges that seem to impact the quality of their professional development programmes. On this basis needs-based professional development programmes can be developed to support MTEs' diverse needs in the professional development system. On the other hand, it may provide MTEs' with lenses for capturing different aspects of their training practices when planning and implementing their PD courses.

While DZLM principles (2013) and the work of other researchers (e.g., Cochran-Smith & Lytle, 1999; Garet et al., 2001; Lipowsky & Rzejak, 2012; Putnam & Borko, 2000) focus on practices for effective PD and the activities of its participants, in the instrument we focused explicitly on the MTE itself, that is, on their actions to achieve the prescribed practices. No matter the situation, the professional developer (here MTE) is a critical protagonist, as he/she is the one who sets goals for a professional development. For that reason, we contend that their doing – as it is when focusing on teachers – should be made the central focus of theoretical frameworks.

With these considerations in mind, we propose here a model in which four interrelated professional development dimensions with respect to MTE's doing stand in focus (see Table 3). This model focuses on 4 dimensions: (1) general MTE's role, (2) nature of selected materials/tasks and its quality (3) role of the MTE when using manipulatives, and (4) established socio-mathematical norms. The first dimension entails practices aligned with learner-orientation. The second dimension focuses on activities in which MTs engage to make the new ideas problematic, connect

MODEL DIMENSIONS AND ITS FACETS
(1) General role of the MTE
— Engages MTs as adult learners in the learning process (e.g., time on tasks, building on existing knowledge, practices, and experiences)
— Integrates in depth knowledge about assessment, curriculum and how to teach it
— MTE and MTs work together on a specific concern about student engagement, learning, etc.
— Makes target goals transparent (e.g., emphasises the important content to know and understand, and why)
— Uses ample opportunities for an on-going assessment of learning
— Integrates MTs' knowledge into an active learning process
(2) Nature of activities and materials
— Allows MTs to build and/or consolidate their professional knowledge
— Challenges MTs existing practices
— Helps MTs focus on student learning
— Helps MTs understand their students' learning, misconceptions
— Allows integration of theory and practice
— Connects with teacher current knowledge and/or practices
(3) Role of the MTE when using manipulatives
— Allows MTs to construct meaning for the tool with respect to the topic
— Supports MTs to use the tool for a purpose (e.g., to better their teaching practices, to consolidate their knowledge and skills)
— Connects the use of tool with MTs' teaching practices
— Connects the use of tool to the topic(s) of interest
(4) Socio-mathematical norms (professional exchange, collaboration)
— MTE uses various instructional format allowing MTs to engage in a variety of continuous teaching-learning scenarios
— MTs have opportunities for discussions (professional exchange) with the MTE and other MTs in professional learning
— Professional learning focuses on MTs' problems in teaching and learning
— MTs can choose issues of interest and share those
— MTs have ample opportunities to share their results, concerns, etc. and to reflect on those
— Continuous learning and learning opportunities are a part of the PD

Table 3: A 4-dimensional model for analysing MTEs' practices with some descriptors

to where the MTs are with respect to their knowledge or practices, and leave behind a mathematical value. Thus, this dimension entails practise aligned with competence development and case-based learning. The third dimensions focuses on manipulatives used to achieve mentioned dimensions. The fourth dimension entails practices aligned with application of various instructional formats, stimulating collaboration and fostering (self-)reflection. Thus, its focuses on normative aspects of professional development discussions that are specific to MTE's mathematical activity.

In our future work we plan to continue developing instruments for examining MTEs' PD programmes. Our goal is to define and develop a descriptive model – on the basis of the above presented protocol and the 4-dimensional model – that would allow us to assign different quality levels (level 1 to level 5) to the five PDs, and PD programmes in general. This would allow giving MTEs a detailed feedback on their practices, and target those facets of professional knowledge that may be either lacking or need to be further developed.

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