THE INFLUENCE OF TEACHER-TRAININGS ON IN-SERVICE TEACHERS' EXPERTISE: A TEACHER-TRAINING-STUDY ON FORMATIVE ASSESSMENT IN COMPETENCY-ORIENTED MATHEMATICS

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The research-project Co²CA investigates the influence of teacher-trainings on in-service teachers' expertise. Within a teacher-training-study 27 in-service teachers have been trained in selected ideas about teaching, having an exemplary focus on central aspects of formative assessment in competency-oriented mathematics. At the end of the teacher-trainings the teachers' pedagogical content knowledge as crucial aspect of teachers' expertise has been evaluated by using tests being sensitive to the teacher-trainings. Results of this evaluation point out: Within teacher-trainings pedagogical content knowledge can be conveyed to in-service teachers successfully.

INTRODUCTION

As part of fundamental debates about effective teaching in general and successful competency-oriented teaching of mathematics in detail the importance of (mathematics) teachers' expertise for students' learning has been pointed out by several studies within the last decade (Ball, Hill & Bass, 2005; Baumert et al., 2010). Next to open questions about how to train pre-service teachers to build up expertise it's furthermore not clear by now how in-service teachers can best be supported building up their expertise. Therefore the interdisciplinary research-project Co²CA [1] investigates the influence of teacher-trainings on teachers' expertise, focusing on selected ideas of teachers' pedagogical content knowledge about assessing and reporting students' performances if dealing with modelling tasks. Within this article, (1) an overview about theoretical and empirical discussions about the role of teachers' knowledge as part of teachers' expertise is given. Furthermore (2) some central ideas about mathematical modelling as part of competency-oriented mathematics as well as (3) empirical findings on assessing and reporting students' performances are pointed out. Based on these considerations (4) a teacher-training-study as part of the research-project Co²CA is presented: research-question, design and test-instruments are illustrated as well as results pointing out the effectiveness of teacher-trainings for building up in-service teachers' expertise.

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TEACHERS' KNOWLEDGE AS CORE DIMENSION FOR THE QUALITY OF TEACHING AND STUDENTS' LEARNING

Nearly the whole 20th century researchers have tried to explain students' learning by investigating the teacher's role for the quality of teaching – once by describing the teachers' personality, once by analysing learning processes and products in classroom, once by assessing teachers' expertise. Especially since the work of Shulman (1986) the idea of harking back to teachers' content knowledge (CK), teachers' pedagogical content knowledge (PCK) and teachers' general pedagogical knowledge (PK) as central aspects of teachers' expertise to explain the quality of teaching and of students' learning is a crucial one. These "three core dimensions of teacher knowledge" (Baumert et al., 2010, p. 135) help to understand the teachers' role in the classroom. By assessing, describing and analysing teachers' CK, PCK and PK, several studies resort to these dimensions of teachers' expertise – and with a special focus on mathematics teachers the COACTIV-project (Baumert et al., 2010), the Michigan Group (Ball, Hill & Bass, 2005) and the TEDS-project (Döhrmann, Kaiser & Blömeke, 2012) point out the importance of CK, PCK and PK for the quality of teaching and for students' learning. And having especially a closer look at teachers' pedagogical content knowledge, Baumert (2010) stresses:

> PCK – the area of knowledge relating specifically to the main activity of teachers, namely, communicating subject matter to students – makes the greatest contribution to explaining student progress. This knowledge cannot be picked up incidentally, but as our finding on different teacher-training programs show, it can be acquired in structured learning environments. One of the next great challenges for teacher research will be to determine how this knowledge can best be conveyed to both preservice and inservice teachers. (Baumert et al., 2010, p. 168)

MATHEMATICAL MODELLING AS ONE ASPECT OF COMPETENCY-ORIENTED MATHEMATICS

Based on general ideas about competency-oriented mathematics (Niss, 2003) several countries implemented national standards for the teaching and learning of competency-oriented mathematics within the last years (see besides others: NCTM, 2000). One of the main ideas of these standards is to not only telling teachers any longer which mathematical content should be taught and learnt at school but to describe which mathematical competencies students should possess at the end of a course. Besides other competencies (e. g. problem solving, reasoning, communicating – see Blomhoj & Jensen, 2007), mathematical modelling is one of these competencies students should acquire if dealing with mathematical topics at school. The main idea of being able to do mathematical modelling is: One should not only be able to solve pure mathematical problems but to work on (complex) real world problems which can be solved by using mathematics. In detail, the competence of mathematical modelling includes (see also Blum, 2011; Maaß, 2010):

- Being able to understand, structure and simplify a complex real world problem and being able to transfer the reduced real world problem into a so called mathematical problem which can be worked on mathematically.
- Being able to work on the mathematical problem mathematically, to interpret and validate the mathematical result by transferring it back to reality and finally being able to give an answer to the initial, proper real world problem.

ASSESSING AND REPORTING STUDENTS' PERFORMANCES WITHOUT GIVING MARKS – THE IDEA OF FORMATIVE ASSESSMENT

Next to fundamental discussions about competency-oriented mathematics the question of how to assess and report students' performances to support students' learning as good as possible is a central question of improving the quality of teaching in general and the quality of teaching mathematics in detail. While in school students' performances are quite often assessed only once at the end of a course and the students is given a mark summarizing their performances which "does not normally have immediate impact in learning" (Sadler, 1989, p. 120), theoretical and empirical studies hint at the importance of a more formative assessment at school (Baker, 2007; Black & William, 2009; Hattie, 2008; Shepard, 2000): Students' performances should be assessed in short intervals and more than once during learning processes, diagnoses of students' performances should immediately be used to support students' learning. As a central element of such a formative assessment, feedback should be given to the students whenever assessing performances which mainly answers three questions: Where am I going? How am I going? and Where to next?" (Hattie & Timperley, 2007, p. 88). Furthermore meta-analyses point out the following ideas of how feedback "with which a learner can confirm, add to, overwrite, tune, or restructure information in memory" (Butler & Wine, 1995, p. 275) as part of formative assessment should look like to support students' progress as good as possible:

- Kluger & DeNisi (1996) stress that feedback should first of all be close to the tasks students are working on: "effects on performance are augmented by (a) cues that direct attention to task-motivation processes and (b) cues that direct attention to task-learning processes" (Kluger & DeNisi, 1996, p. 268).
- Deci, Koestner & Ryan (1999) emphasize that feedback should inform students concerning their learning processes without any kind of pressure. Furthermore the information provided to the students should not only tell the student whether he is right or wrong but offering additional information about how to improve (see also Bangert-Drowns, Kulik, Kulik & Morgan, 1991; Pittman, Davey, Alafat, Wetherill & Kramer, 1980).

A TEACHER-TRAINING-STUDY FOR IN-SERVICE TEACHERS

Based on theoretical and empirical discussions (1) about the importance of teachers' expertise for the quality of teaching and for students' learning, (2) about competency-oriented mathematics in general and mathematical modelling in detail and

(3) about the importance of feedback as central element of formative assessing and reporting students' learning, within a teacher-training-study the research-project Co²CA aims at answering the following research-questions:

Research-question I

Is it possible to develop tests on teachers' expertise being sensitive to the topics of a teacher-training? Or more specifically: Is it possible to develop tests on teachers' pedagogical content knowledge concerning formative assessment if dealing with modelling tasks in competency-oriented mathematics which can be used to evaluate a teacher-training reliably?

Research-question II:

Is it possible to support teachers building up their expertise if attending in teacher-trainings? Or more specifically: Is it possible to foster teachers' pedagogical content knowledge concerning formative assessment if dealing with modelling tasks in competency-oriented mathematics if teachers are trained in these topics?

Design and content of the teacher-training-study

For being able to answer the main research-questions stated above, the following teacher-training-study as one part of the research-program of Co²CA looks like as follows (see also figure 1): Overall 27 mathematics teachers participate in teacher-trainings taking place from September 2013 to December 2013. Before starting the trainings every single teacher is assigned to one out of two experimental groups (EG A and EG B). Over a period of 10 weeks there are three-day teacher-trainings twice for these two experimental groups, once at the beginning of the teacher-training-study, once at the end of the teacher-training-study.

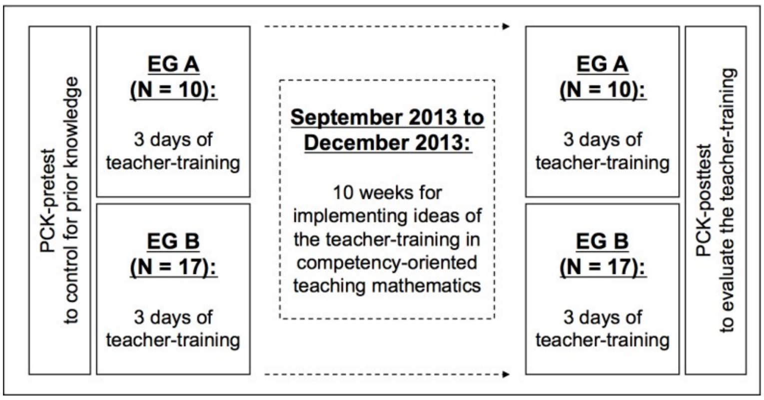


Figure 1: Design of the teacher-training-study

The contents of the teacher-trainings differ between the two experimental groups: Teachers of EG A are trained in central ideas of formative assessment if dealing with modelling tasks in competency-oriented teaching of mathematics, teachers of EG B are trained in selected aspects of competency-oriented mathematics in general (see table 1 for details). Next to taking part in the teacher-trainings itself the participating teachers have to implement central ideas of the teacher-trainings within their teaching mathematics at school, that is to assess and report students' modelling performances regularly (EG A) respectively to make use of problem-solving-tasks and modelling-tasks (EG B) if teaching mathematics.

EG A	EG B
(1) Formative assessment and feedback as central element of formative assessment: A general psychological and pedagogical point of view.	(1) Mathematical problem solving as a central element of competency- oriented mathematics: General didactical ideas and task-analyses.
(2) Mathematical modelling as a central element of competency- oriented mathematics: Analysing students' solution processes and giving feedback to the students.	(2) Mathematical modelling as a central element of competency- oriented mathematics: General didactical ideas and task-analyses.
(3) Implementing formative assessment in teaching mathematical modelling.	(3) Implementing mathematical problem solving and mathematical modelling in every-day teaching.

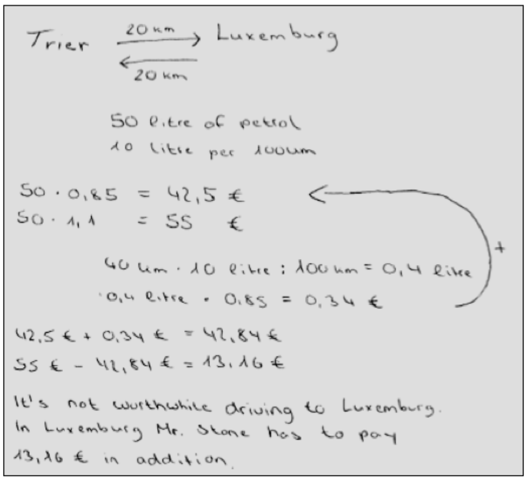
Table 1: Contents of the teacher-training-study

Test-instruments to evaluate the teacher-training-study

For being able to evaluate the teacher-training-study and to evaluate the effectiveness of the trainings, the following test-instruments are used within the study to compare the teachers' pedagogical content knowledge of the two experimental groups:

- Firstly a pretest on teachers' mathematical pedagogical content knowledge is used at the beginning of the training to control for teachers' PCK. This test is taken from the COACTIV-project (see e. g. Krauss et al., 2008) and asks for general didactical ideas if teaching mathematics.
- Secondly there is a newly developed posttest on teachers' PCK which is used to compare the teachers' expertise between the two experimental groups at the end of the teacher-training-study and which is sensitive to the contents of the teacher-trainings in EG A. In detail this PCK-posttest consists of overall 10 items dealing with (1) ideas about mathematical modelling processes in general as well as with (2) ideas about how to analyse students' solution processes to modelling tasks. Furthermore it is asked (3) for how to give feedback to students working on modelling tasks and (4) for concepts of how to implement formative assessment in teaching mathematical modelling (an example of an item of this PCK-posttest is given in figure 2).

There is given the following task on the left and a students' solution to the task on the right:

Task:	**Students' Solution:**
Mister Stone lives in Trier close to the border of Luxemburg. For filling up his VW Golf he drives to Luxemburg. Immediately behind the border, which is 20 km away from Trier, there is a petrol station. There you have to pay 0.85 Euro for one litre petrol in contrast to Trier where you have to pay 1.1 Euro. Is it worthwhile for Mister Stone to drive to Luxemburg?	

Give a written feedback to the student which has a great potential to support further learning of the student.

Figure 2: An example of a PCK-posttest-item

Results of the teacher-training-study

By January 2014, the PCK-posttest has been coded completely (whereas data of the PCK-pretest still has to be analysed): For every single item, teachers' are given – depending on the item – up to 3 score-points, by theory a minimum of 0 score-points and a maximum of 21 score-points is possible. Based on this coding the following answers to the research questions stated above can be given (see also table 2):

- Research Question I: The PCK-posttest is reliable with Cronbach's alpha = 0.68 regarding the whole sample of 27 teachers within EG A and EG B.
- Research Question II: Having a closer look at the teachers' performances to the PCK-posttest, it can be seen that teachers of EG A outperform their counterparts of EG B. In detail, teachers of EG A do not only score a higher empirical maximum but do also have a significantly higher mean-score in the PCK-posttest ($t(25) = 4.90$; $p < .001$). The effect-size of this difference is a medium one, that is Cohen's d for independent samples with a differing sample size is $d = 0.7$.

PCK-posttest: 10 items; alpha = 0.68 (N = 27)

	N	m	SD	emp. min.	emp. max.		
EG 1	10	15.10	1.91	12	18	p < .001	d = 0.7
EG 2	17	9.65	3.18	2	14		

Table 2: Results of the PCK-posttest

SUMMARY AND OUTLOOK

Teachers' expertise has been pointed out to be central for the quality of teaching. However it is still an open question how to support teachers building up their expertise. Within the research project Co²CA a test on teachers' expertise has successfully been developed which is not only sensitive to the content of teacher-trainings but which can furthermore reliably be used to evaluate teachers' expertise at the end of trainings. Results using this instrument illustrate that teachers' expertise is significantly higher if they are specifically trained within the topics being tested comparing to teachers not being trained. So it is not only general knowledge about competency-oriented mathematics which is needed to answer the posttest-items (EG B) but special knowledge about formative assessment if dealing with modelling tasks (EG A). Within the next steps the PCK-pretest has to be analysed to control for teachers' general didactical knowledge. Furthermore results presented here have to be discussed within the broader context of the research-program of Co²CA to investigate the influence of teacher-trainings on teachers' expertise in depth.

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