Mathematics-related Competence of Early Childhood Teachers Visiting a Continuous Professional Development Course: An Intervention Study

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Recent studies highlight early childhood teachers' mathematics-related competence. Developing this competence should be a main aspect of early childhood teachers' education. This is, however, not the case in all countries. Consequently, high-quality professional development courses are needed. Based on research results, we developed a competence-oriented continuous professional development course (*EmMa*) and examined the effects of *EmMa* by asking: How does *EmMa* affect the development of early childhood teachers' i) mathematical content knowledge, ii) mathematical pedagogical content knowledge and iii) beliefs towards mathematics in general? To answer these questions, we conducted a pre-test/post-test study including a control group with 99 in-service early childhood teachers. Results show that the course affected teachers' mathematical pedagogical content knowledge and static orientation towards mathematics positively. From this we conclude that scaling-up *EmMa* might be a suitable approach to bridge the gap between pre-service education with nearly no mathematics and the challenges of early mathematics education.

Keywords: early childhood teachers • mathematics-related competence • professional development • teacher knowledge • beliefs

Introduction

High-quality early mathematics education is of great relevance to foster the mathematical learning of all children (Lee & Ginsburg, 2007; Lehrl, Kluczniok, & Rossbach, 2016; Melhuish et al., 2013; Melhuish et al., 2008). Early mathematics education in this sense focuses on fostering early mathematical skills by playing, communicating and accumulating varied mathematical experiences in a stimulating environment (e.g., Clements, 2004). A key characteristic of high-quality early mathematics education is learning mathematics in everyday situations, in natural learning settings (Gasteiger, 2014; van Oers, 2010). Implementing this way of mathematical learning in kindergarten, however, needs an early childhood teacher who recognises mathematical opportunities in everyday situations and helps a child to use these opportunities as learning situations. Teaching this way places high demands on the competence of early childhood teachers, which differ greatly from the demands faced by primary or secondary school teachers (Anders & Rossbach, 2015). As natural learning situations are rarely planned, early childhood teachers need knowledge of the mathematics relevant to early childhood learning and beyond as well as skills to recognise mathematics in everyday situations. Additionally, they need to know how mathematical skills develop to be able to interpret the learning level of the child in that situation. Finally yet most importantly, early childhood teachers need knowledge and skills to design mathematical learning environments that offer children adequate support in their mathematical learning (Anders & Rossbach, 2015; Gasteiger, 2012).

Developing this professional competence in the fields of mathematics should be one of the main aspects of early childhood teachers' education. This is, however, not the case in all countries (e.g., Germany). Although there are a growing number of teacher education programs integrating early mathematics education (Mischo, 2015; Strohmer & Mischo, 2016), there are still early childhood teachers that are not adequately trained to teach mathematics in kindergarten. For example in Germany, where our study took place, early education prioritised socioemotional development for a long time. Official curricular guidelines for early childhood education that focus on children's (pre)academic skills were introduced only ten years ago (Anders & Rossbach, 2015). Thus, in contrast to other countries (e.g., Switzerland; Australia), early childhood teachers' education in Germany still offers few opportunities to learn how to support mathematical learning in kindergarten. Most of the early childhood teachers working today "were trained many years ago when the promotion of (pre)academic skills, school readiness, and emerging mathematics were not considered the main educational goals" (Anders & Rossbach, 2015, p. 307). To support these early childhood teachers to cope with the curriculum changes, teachers need to be provided with learning opportunities in the field of early mathematics education (see also Copley, 2004; Copley & Padrón, 1998; Sarama & DiBiase, 2004). To develop suitable learning opportunities for in-service teachers, it is important to address the problem of skills and knowledge relevant to teach mathematics in kindergarten and to identify suitable professional development approaches. Thus, below we first describe the synthesis and evaluation of the research on early childhood teachers' mathematics-related competence. In the following section we present research on professional development courses with a special focus on early mathematics education. As a result of these two sections, we describe our continuous professional development course *EmMa* followed by the design and the results of our study on the success of our approach concerning early childhood teachers' competence development.

Mathematics-related Professional Competence of Early Childhood Teachers

Previous studies on teacher competence in the field of mathematics education used analytic approaches to identify cognitive and motivational resources that underlie good mathematics teaching ('performance') (Blömeke & Delaney, 2012; Hill, Loewenberg Ball, & Schilling, 2008; Shulman, 1986). Lately, several authors have highlighted early childhood teachers' mathematics-related competence and its relevance to children's mathematical learning (e.g., Anders & Rossbach, 2015; Bruns, 2014; Dunekacke, Jenßen, & Blömeke, 2015a; Gasteiger, 2014; McCray & Chen, 2012; Tsamir, Tirosh, Levenson, Tabach, & Barkai, 2014). They emphasise that teaching mathematics in kindergarten needs competencies that differ from competencies needed for teaching mathematics in school. Below, we therefore delineate the aspects of professional knowledge and beliefs with respect to this early childhood teachers.

Professional Knowledge of Early Childhood Teachers in the Field of Mathematics

Different studies on early childhood teachers' competence adapt the concept of professional knowledge, which draws on the work of Shulmann (1986) and distinguishes inter alia mathematical content knowledge (MCK) and mathematical pedagogical content knowledge (MPCK), to the early childhood context (Gasteiger & Benz, in press; Jenßen, Dunekacke, Eid, & Blömeke, 2015; McCray & Chen, 2012). As "preschool mathematics comprises different content than elementary or secondary school mathematics" (Anders & Rossbach, 2015, p. 308), mathematical content knowledge for early childhood teachers consequently differs from the constructs already established for primary and secondary school teachers (see also Gasteiger & Benz, in press). While the curriculum and the mathematical background of these topics define mathematical content knowledge for school teachers, mathematical content knowledge for early childhood teachers is not that easy to deduce. Various authors consider mathematical content knowledge for early childhood teachers as a conceptual understanding of the mathematical content of primary school in the areas number and operations; measurement, quantity and relation; geometry; data, combinatorics and chance (Anders & Rossbach, 2015; Blömeke, Jenßen et al., 2015). In addition, some authors incorporate knowledge about process-related competencies, such as problem solving, modelling, communicating, representing, reasoning and pattern and structuring (Jenßen et al., 2015). Oppermann, Anders, and Hachfeld (2016), however, note that there is no consensus on the mathematical expertise required for early childhood teachers.

Mathematical pedagogical content knowledge as introduced by Shulman (1986, p. 9) is knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" and includes "the ways of representing and formulating the subject that make it comprehensible to others". Connecting this definition to the early childhood context means to take the special characteristics of early childhood teaching into consideration. Early mathematics education takes place in natural learning settings and often has a less formal character than learning in school (Gasteiger, 2012; van Oers, 2010). In consequence, mathematical pedagogical content knowledge for an early childhood teacher differs from primary or secondary school teachers' mathematical pedagogical content knowledge (see also Gasteiger & Benz, in press). Mathematical pedagogical content knowledge for early childhood teachers is seen as knowledge about ways to analyse mathematical development, to create mathematical learning environments for young children and give adaptive support in natural learning settings. To measure early childhood teachers' mathematical pedagogical content knowledge we found two different approaches in the research literature. McCray and Chen (2012) and – in reference to McCray and Chen – also Anders and Rossbach (2015) focus on a situated approach by operationalising mathematical pedagogical content knowledge as the sensitivity to capture mathematical content in children's play. Dunekacke, Jenßen, and Blömeke (2015b) chose a cognitive approach and measure knowledge on how to foster mathematical literacy in informal and formal settings, the development of children's mathematical skills as well as how to analyse and support this development using a paper pencil test.

Mathematics-related Beliefs of Early Childhood Teachers

Beliefs are in general defined as "understandings, premises or propositions about the world that are felt to be true" (Richardson, 1996, p. 103) and often described as lenses that shape how teachers design mathematical activities and set learning goals for children (e.g., Leder, Pehkonen, & Toerner, 2002). Beliefs about mathematics in general describe a person's view on mathematics (Benz, 2012). Teachers that hold a static orientation (SO) see mathematics as an abstract structure and believe that new mathematical concepts can only be defined by proofs. In contrast, teachers that hold a process-related orientation (PO) believe that mathematics starts with real problems and that mathematics is mainly an activity to solve problems. The application-orientation (AO) incorporates the opinion that mathematics has an application in real life. These beliefs influence what teachers consider to be worth teaching.

McCray and Chen (2011; see also Chen, McCray, Adams, & Leow, 2014) emphasise the importance of reconciling early mathematics teaching with beliefs concerning developmentally appropriated teaching to assure early mathematics gets the attention it requires (see also Denny, 2009; Upadyaya & Eccles, 2014). They argue that early childhood teachers see math teaching as pushing down a formal curriculum and therefore inappropriate for early childhood settings. Understanding mathematics as a process rather than a set of rules could support the idea of teaching mathematics in a child-initiated, developmentally appropriate way. Research results by Benz (2012), however, support the assumption that early childhood teachers' beliefs are static. Only 4% of the examined early childhood teachers in Germany agreed mainly to the aspect of process. Furthermore, early childhood teachers narrow mathematics to numbers and operations (Benz, 2012; Lee & Ginsburg, 2007) and are "often unaware of essential processes of mathematics, specifically, reasoning, problem solving [and] connections between mathematics and the world of the young child" (Copley, 2004, 402f.).

Overall, it seems arguable that early childhood teachers do need a well-developed beliefs-system to support children's early mathematical learning (Anders & Rossbach, 2015; Benz, 2012; Copley & Padrón, 1999; Lee & Ginsburg, 2007; Sarama & DiBiase, 2004).

Empirical Results on the Relations between Aspects of Early Childhood Teachers' Competence and Children's Learning Outcomes

Besides professional knowledge and beliefs teacher competence models integrate skills in actual teaching (performance) and more recently process-related skills, as perception, interpretation and decision-making (e.g., Blömeke, Gustafson, & Shavleson, 2015; Gasteiger & Benz, in press). These process-related skills are considered to function as a bridge between knowledge and performance. Altogether, the construct of teacher competence is assumed to effect children's mathematical learning (Gasteiger & Benz, in press). To support early childhood teachers' mathematics-related competence to foster children's mathematical learning effectively one therefore needs to consider the different aspects of teacher competence and their relation to each other. Empirical results contribute to clarifying the relations between these different aspects and their connection to children's learning outcomes.

Concerning early childhood teachers there are several studies examining different aspects of the competence construct. Figure 1 systemises some of the results. In these studies, perception is described as the skill to identify mathematics in children's play and to recognise natural learning situations. Interpretation refers to the analysis of children's mathematical development; decision-making focuses on the planning of mathematical activities for children as well as the spontaneous act of offering support in a natural learning situation (see also Gasteiger & Benz, in press). While there are several relations between the knowledge facets and the beliefs (Anders & Rossbach, 2015; Dunekacke, Jenßen, Eilerts, & Blömeke, 2016; Jenßen et al., 2015), Figure 1 also shows that empirical results support the idea of situation specific skills functioning as a structural relation between knowledge and beliefs on the one side and actual teaching skills on the other. The results indicate that mathematics-related knowledge and affective-motivational aspects influence at least the skills in perceiving mathematics in children's play and the skills in decision-making (Dunekacke et al., 2015a; Dunekacke et al., 2015b; Dunekacke et al., 2016; Wittmann, Levin, & Bönig, 2016). Bruns (2014) showed a relation between the situations specific skills and the quality of mathematics teaching in kindergarten. In addition, mathematical pedagogical content knowledge (McCray & Chen, 2012) and affective-motivational aspects (Lee, 2010) affect early childhood teachers' teaching, which is in turn, directly linked to children's mathematical learning (Donie, Kammermeyer, & Roux, 2013; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Lehrl et al., 2016).

Taken as a whole the results strengthen the idea that a competent early childhood teacher integrates various aspects of competence but needs well-developed mathematics-related knowledge and beliefs as a basis to foster early mathematical learning in a successful way.

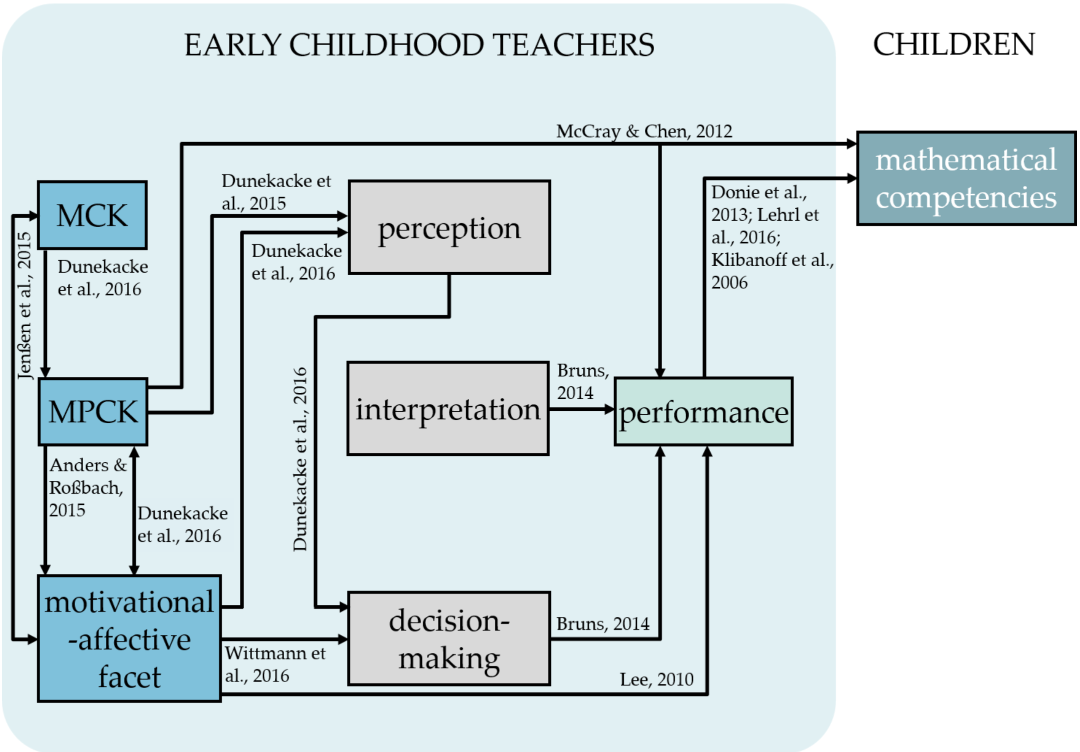

Figure 1. Relations between early childhood teachers' competence and children's learning outcome (arrows indicate relationship as reported by the authors of the studies: double arrows indicate a correlation, simple arrows indicate a direct relationship).

Continuous Professional Development Concerning Early Mathematics

As mentioned above, there is a need for professional development courses on early mathematics education that "bridge the gap between pre-service-education [with nearly no mathematical content] and the requirement to encourage mathematical learning in early childhood education" (Gasteiger, 2012, p. 195). This applies especially to Germany but also to other countries with recent curriculum changes such as USA or Australia (e.g., Perry & Dockett, 2013; Sarama & DiBiase, 2004).

As a foundation for the development of such a course, it is important to develop an overview on suitable topics and design principles of professional development courses. In the following, we therefore illustrate characteristics of effective professional development and empirical results on effects of professional development. Afterwards, we present our professional development course *EmMa* by exemplifying its design principles.

Characteristics of Effective Professional Development Courses

A professional development course should enable early childhood teachers to create a high-quality learning environment and to support children in their mathematical learning processes. From research on effective professional development in general, it is known that professional development takes time. Based on a meta-analysis, Yoon, Duncan, Lee, Scarloss, & Shapley (2007) suggest a minimum duration of 53 hours for effective professional development. Consequently, a professional development course should be continuous rather than a one-day training. Additionally, combining presence and practical phases has proved to be a key factor for gaining lasting effects with professional development courses (e.g., Lipowsky & Müller, 2010; Lipowsky & Rzejak, 2012; Sarama & DiBiase, 2004).

Concerning the content of professional development courses, different authors recommend to focus not only on counting and cardinality but to draw a versatile picture of mathematics (e.g., Benz, 2012; Simpson & Lindner, 2014; Zaslow, Tout, Halle, Whittacker, & Lavelle, 2010). Moreover, a continuous professional development course should not only present hands-on materials but also support the development of early childhood teachers' competence in the sense described above (e.g., Gasteiger, 2012; Sarama & DiBiase, 2004; Simpson & Lindner, 2014). This competence-oriented approach would include opportunities to develop knowledge about relevant mathematics for early childhood education, knowledge about mathematical development-processes, tools to observe and document mathematical development, especially in play situations and criteria to evaluate materials for mathematical learning (Gasteiger, 2012; Sarama & DiBiase, 2004).

In summary, it can be stated that effective professional development courses on early childhood mathematics education are long lasting, competence-oriented and foster a broad understanding of mathematics related to several content areas.

Empirical Results on Effectiveness of Continuous Professional Development Courses

Empirical results indicate that well developed continuous professional development courses can support the mathematical teaching practice of early childhood teachers (Clements & Sarama, 2008; Rudd, Lambert, Satterwhite, & Smith, 2009). Furthermore, these courses show positive effects on self-reported competence (Arnold, Fisher, Docotroff, & Doobs, 2002) and attitudes towards teaching mathematics (Arnold et al., 2002; Ciyer, Nagasawa , Swadener, & Patet, 2010). The last result is especially important, as beliefs are comparatively hard to change (e.g., Grigutsch et al., 1998). Research with primary and secondary school teachers shows inconsistent results concerning the impact of continuous professional development courses on the development of beliefs (positive impact: e.g., Carney, Brendefur, Thiede, Hughes, & Sutton, 2014; Stohlmann, Cramer, Moore, & Maiorca, 2015; no impact: e.g., Dede & Karakus, 2014). Research with beginning primary teachers, points to a shift to more process-oriented beliefs in teachers' first years of practice (Blömeke, Hoth et al., 2015).

A few studies also measured effects of continuous professional development courses on selected aspects of early childhood teachers' pedagogical content knowledge (Platas, 2014; Tsamir et al., 2014). While Tsamir and colleagues (2014) found that early childhood teachers' enhanced their knowledge of their young students' number conceptions in a continuous professional development course, Platas (2014, p. 127) reported that the "enrollment in a M.A. mathematical development course was associated with a significant increase in the participants' knowledge of early mathematical development". No study on the effects of continuous professional development on early childhood teachers' mathematical content knowledge was identified. However, different studies with early childhood teachers show effects of continuous professional development on mathematical learning of pre-school children (e.g., Arnold et al., 2002; Clements & Sarama, 2008, Gasteiger, 2014; Tirosh, Tsamir, Levenson, & Tabach, 2011).

Nevertheless, looking at the current state of research there is a lack of studies on the development and support of mathematics-related knowledge and beliefs in in-service early childhood teacher education. This is especially true for the effects on different facets of early childhood teachers' mathematics-related competence (Zaslow et al., 2010), as for example early childhood teachers' mathematics-related knowledge and beliefs.

Continuous Professional Development Course: EmMa

In spite of the positive research results concerning the effects of continuous professional development, continuous professional development courses on the topic of early mathematics education that are designed along the characteristics described above are rare (Ginsburg et al., 2006; Simpson & Lindner, 2014). Most of the offered courses last only one-day (Baumeister & Grieser, 2011; Simpson & Lindner, 2014) and focus on hands-on materials rather than knowledge in specific mathematical content areas such as number and operations, geometry, or measurement (Simpson & Lindner, 2014). In consequence, we decided to develop a continuous professional development course on early mathematics education. Based on theoretical background on early mathematics education, demands for early childhood teachers concerning their mathematics-related competence and characteristics of successful continuous professional development courses we designed *EmMa – Erzieherinnen und Erzieher machen Mathematik* (Early childhood teachers are doing mathematics) (see also Bruns & Eichen, in press). The design of the course was guided by the design principles of the German Center for Mathematics Teacher Education (DZLM), namely competence-orientation, participant-orientation, case-relatedness, various instruction formats, stimulation cooperation and fostering (self-)reflection. The design principles derived from empirical findings on continuous development courses (see also Barzel & Selter, 2015; Roesken-Winter, Stahnke, Schueler, & Bloemeke, 2015).

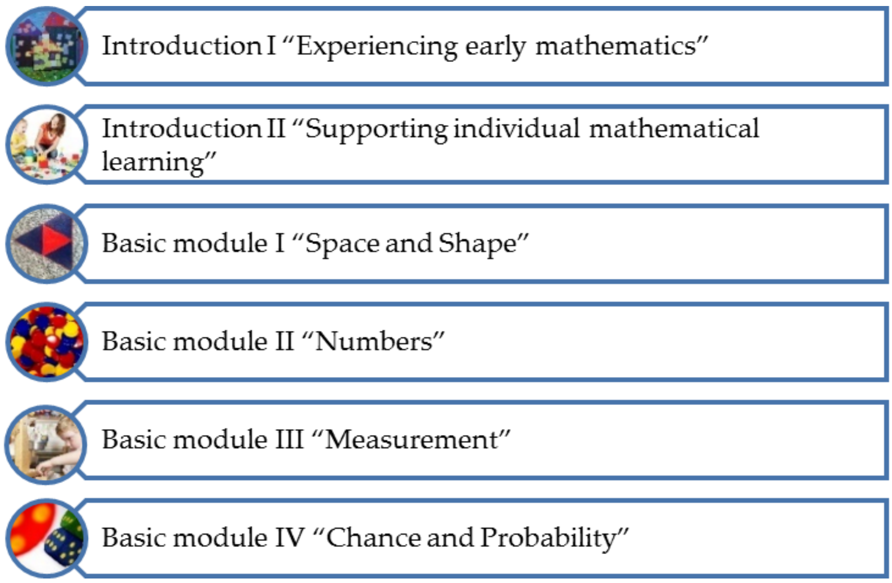

Figure 2. Course design of *EmMa.*

Concerning the competence-orientation, *EmMa* focusses on subject specific knowledge, skills and beliefs. One aim of the continuous professional development course is that early childhood teachers expand and deepen their basic mathematical knowledge. Therefore, the participants experience mathematics by actively engaging in problem solving and argumentation. Concerning the mathematical pedagogical content knowledge, early childhood teachers should acquire knowledge on the development of mathematical skills, analysing children's mathematical learning levels, providing adaptive support, and recognising and creating mathematical learning opportunities for children. To achieve this, *EmMa* emphasises mathematical learning within natural learning situations and focuses on basic mathematical skills in all content areas. Additionally, the participants get support in analysing the mathematical content of different materials and everyday situations in every session.

Beyond the development of mathematical content knowledge and mathematical pedagogical content knowledge, another aim of the continuous professional development course *EmMa* is to address the beliefs of early childhood teachers. The participants get opportunities to experience mathematics as a process, as a dynamic science. They engage in mathematical problem solving and discuss different strategies. Additionally, children's problem solving strategies and learning processes are analysed from a constructivist perspective. Thereby, the participants are encouraged to reflect on their own perception of mathematics.

In line with empirical findings on effective continuous professional development courses (Lipowsky & Müller, 2010; Lipowsky & Rzejak, 2012), *EmMa* combines presence and practical phases and thereby uses various instruction formats (Barzel & Selter, 2015, Roesken-Winter et al., 2015). As shown in Figure 2 *EmMa* comprises two introductory and four basic modules. Overall, the course lasts one year and has a workload of approximately 100 hours. The basic modules address different content areas of pre-school mathematics. Each module lasts one day (presence phases). During the presence phases, *EmMa* combines theoretical input phases, phases of self-reflection, and mathematical experiences. Furthermore, *EmMa* follows the principle of participant-orientation (Barzel & Selter, 2015, Roesken-Winter et al., 2015), which includes an intensive discussion concerning the teachers' own mathematical experiences and their view on mathematics. In between the presence phases, the early childhood teachers apply their newly acquired knowledge in practice. During these practical phases, the teachers document their children's work.

Another key design principle of the continuous professional development course is to work with case studies (Barzel & Selter, 2015, Roesken-Winter et al., 2015) presented in short video sequences. Based on these video sequences the perception of mathematical content in specific situations and the interpretation of the situations facing the math skills of the children are promoted. For example, in the basic module "Numbers" a short video sequence is used which shows two girls setting the table for six persons. This is an everyday situation in early childhood education, which is often attributed high mathematical potential but rarely specified. Figure 3 shows a screen shot of the analysed situation.

Figure 3. Video sequence “Setting the table“.

First, the two girls both put glasses and plates on the table without communicating with each other. Each glass is paired to one plate. Finally, the girl notices that the number of plates does not coincide with the number of people. She begins to put the plates aside, counts the plates and takes two plates and glasses away. Six plates and six glasses remain on the table. In the second part of the video, the children are looking for chairs. They find two chairs. Without counting, they state that there are not enough chairs. Asked how many chairs are still missing, the girl assigns each place a person and says: "We still need for Lars and you and for these two". In the third part of the sequence, the early childhood teacher asks the other girl for how many people she set the table. The girl answers without counting: "Five!" (Actually, there are six plates). The early childhood teacher does not realise her mistake and asks how many people they are. The girl counts six people and gets another plate and glass. Now the table is set for seven people. The first girl comes back and tries again to establish that there were already a plate and a glass available for each person. She is visibly irritated.

The analysis of this situation shows different relevant mathematical aspects, as for example counting, one-to-one correspondence, comparison of two quantities and subitising. In the continuous professional development course, the analysis of video sequences is initially done in pairs and then in small groups (stimulating cooperation). In plenary, the substantive aspects of the sequence are collected. In this way, the perception of mathematical aspects in play and everyday situations is promoted. Afterwards, the participants discuss ways of supporting the learning processes of the children. In this example, the early childhood teachers could support the mathematical reasoning of the first girl by asking her why she is irritated. Furthermore, different ways of verifying her hypothesis – that there are enough plates for everyone – could be discussed (e.g., counting, one-to-one correspondence).

In addition to the presented elements of the course, *EmMa* gives the participants several opportunities to reflect their conceptions, attitudes and practices (self-reflection). Every session begins with a reflection phase that encourages the participants to exchange their experiences made in the practical phase with each other. In these discussions, the early childhood educators find different interpretations of one situation, stimulate each other’s practice and accumulate mathematical activities for different topics. This supports not only the teachers’ instructional strategies but also their conceptions of and attitudes about mathematics education in early childhood.

Research Questions

It has been established that early mathematics education is crucial to children's mathematical learning. To foster children's mathematical learning in kindergarten early childhood teachers' competence is seen as a key factor. If, however, teacher competence in the field of mathematics education is not a key factor of teacher education and training, as it is the case in Germany, continuous professional development is seen as a suitable approach to fill this gap. In this study, we developed the continuous professional development course *EmMa* in line with empirical results on effective professional development courses and guided by the design principles of the German Center for Mathematics Teacher Education (DZLM). The aim of the course is to support early childhood teachers' competence in the field of mathematics education. To evaluate teachers' competence development and thereby the success of our approach, we focused on mathematics-related knowledge and beliefs of early childhood teachers, as these are stated above, linked directly or indirectly to several competence facets (see Figure 1). In particular, we pursued the following research questions:

How does the continuous professional development course influence the development of early childhood teachers':

1. mathematical content knowledge?
2. mathematical pedagogical content knowledge? and
3. mathematics-related beliefs?

Research Design

To examine the development of early childhood teachers' mathematics-related knowledge and beliefs we conducted a study in pre-test/post-test design with a control group (see Figure 4). The first two authors carried out the continous professional development course *EmMa* (intervention).

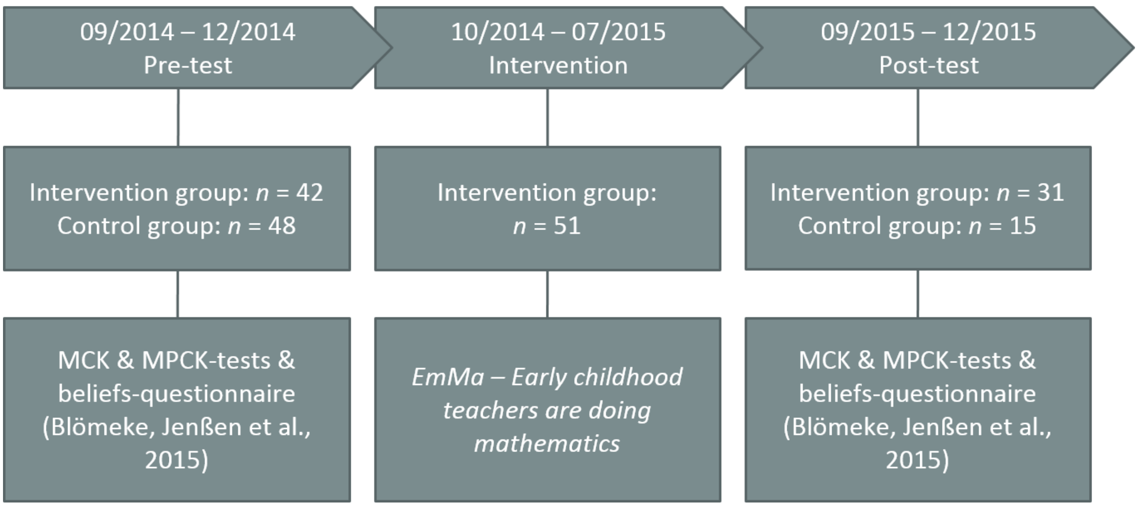

Figure 4. Design of the study.

Sample

We examined our research questions with a convenience sample drawn from the 10 largest pre-schools (N = 453 pre-schools) in Berlin. The original sample consisted of N = 99 early childhood teachers with 51 participants of *EmMa* (intervention group) and 48 in a control group, which have not participated in *EmMa*. The average age of the participants was 45 years and 5 months. Only 5 participants were males. Due to the voluntary participation in the study – no benefits could be given to the participants – not all early childhood teachers participated in both times of measurements. In the intervention group, the data of 9 participants at the pre-measurement point and 20 at post- measurement are missing. Of the 20 missing participants at the post-measurement, 7 finished the continuous professional development course early and therefore, were unavailable for the post-measurement. No systematic dropout could be detected. In the control group, we do have a systematic dropout as the participants who did not take part in the post-measurement showed significant lower pre-test scores. Hence, only the data of those control group participants from which complete data sets are available are analysed. By this measure, bias in the control group could be reduced, even if the sample of the control group is also considerably reduced.

Instruments

To verify the effects of the continuous professional development course on mathematical pedagogical content knowledge and mathematical content knowledge, Rasch-scaled tests (Blömeke, Jenßen et al., 2015) were applied. The mathematical content knowledge test consists of 24 items, which are mainly multiple choice, and partly in open format. Topics of the tests are numbers and operations; measurement, quantity and relation; geometry; data, combinatorics and chance. The test measures mathematical content knowledge at a secondary school level. Mathematical pedagogical content knowledge is tested in the following areas: fostering mathematical literacy in informal and formal settings, knowledge about development of mathematical literacy, analysing and promoting early mathematical skills. The test consists of 35 items. Most of them are in multiple choice and some in open format. Both tests have already been used in another German project with pre-service early childhood teachers and are proved valid (Dunekacke et al., 2016; Jenßen et al., 2015).

The beliefs towards mathematics in general were assessed by a questionnaire (Blömeke, Jenßen et al., 2015) which is based on the work of Grigutsch, Raatz, and Törner (1998) and Benz (2012). It distinguishes three beliefs facets: a static orientation (SO, "Hallmarks of mathematics are clarity, precision and unambiguousness"), a process-related orientation (PO, "Mathematics is an activity involving thinking about problems and gaining insight") and an application-orientation (AO, "Mathematics helps solving everyday problems and tasks"). The 17 items (6 AO-items, 7 SO-items and 4 PO-items) are rated on a 6-point Likert scale from "strongly disagree" to "strongly agree" (Dunekacke et al., 2016).

Analysis

For the analysis of the development of mathematical pedagogical content knowledge and beliefs 31 complete data sets of the intervention group and 15 of the control group were available. For the analysis of the development of mathematical content knowledge, 26 complete data sets of the intervention group and 13 of the control group were available. We found no significant group differences looking at age, work experience and last math grade between the control and intervention groups. Therefore, we assume comparability of the control and intervention group. In order to examine the effect of the intervention, we conducted a repeated measure ANOVA.

Results

Looking at mathematical content knowledge the results of the repeated measure ANOVA revealed no significant main effect, neither of the time of measurement ($F(1, 37) = .23$, $p > 0.05$) nor the treatment group ($F(1, 37) = .639$, $p > 0.05$). There was also no interaction effect ($F(1, 37) = .45$, $p > 0.05$). Looking at the results concerning mathematical pedagogical content knowledge there was a significant main effect of the time of measurement ($F(1, 44) = 4.47$, $p = 0.04$, $\eta_p^2 = .092$) but no main effect of the treatment group ($F(1, 44) = 2.04$, $p > 0.05$). There was, however, a significant interaction effect between the time of measurement of mathematical pedagogical content knowledge and the treatment group ($F(1, 44) = 5.62$, $p = 0.02$, $\eta_p^2 = .113$).

Concerning the beliefs, we examined the application orientation, the static orientation and the process-related orientation. At the beginning of the study, both groups showed a high agreement on all three beliefs facets (see Table 1). As we detected a ceiling effect[1] on all application orientation items in the pre-test measurement of the intervention group, it was not possible to detect any further development with this instrument and we excluded this scale from the analysis. In a next step, we examined if our continuous professional development course influenced the two remaining beliefs facets. Looking at the static orientation there was no significant main effect neither of the time of measurement ($F(1, 39) = 2.05$, $p > 0.05$) nor the treatment group ($F(1, 39) = .03$, $p > 0.05$). We found, however, a significant interaction effect between the time of measurement of the static orientation and the treatment group ($F(1, 39) = 7.99$, $p = 0.007$, $\eta_p^2 = .17$). The results of the analysis of the process orientation revealed no significant main effect neither of the time of measurement ($F(1, 39) = .82$, $p > 0.05$) nor the treatment group ($F(1, 39) = .01$, $p > 0.05$) and no interaction effect ($F(1, 39) = .34$, $p > 0.05$).

Table 1
Descriptive Statistics Concerning the Beliefs Facets

			Static Orientation (SO)		Process Orientation (PO)		Application Orientation (AO)	
		n	*M*	*SD*	*M*	*SD*	*M*	*SD*
Intervention group	t_1	42	4.30	0.75	4.42	0.95	4.88	0.63
	t_2	31	3.91	0.83	4.51	0.87	5.16	0.52
Control group	t_1	15	4.12	1.09	4.47	1.04	4.79	0.90
	t_2	15	4.32	0.69	4.52	0.50	5.00	0.79

Discussion

The continuous professional development course *EmMa* was developed based on empirical results i) on the mathematical competence of early childhood teachers, ii) on continuous professional development and iii) on early mathematics education in general. During the course, both mathematical aspects and aspects of mathematics education were discussed within the

[1] A ceiling effect specifies an error of measurement when most of the subject choose a category at the top which leads to little variance. In our case 21% or more of the participants of the intervention group chose the highest category (6) in the pre-test indicating a ceiling effect.

scope of the different content areas (Space and Shape, Numbers, Measurement, Chance and Probability).

The intervention study focused on the development of mathematical content knowledge, mathematical pedagogical content knowledge and beliefs concerning mathematics in general in relation to the continuous professional development course. We conducted a quasi-experimental study with a control group. Our results need, however, to be viewed within the limitations of the study. For example, all early childhood teachers of the control group took part voluntarily in the study and were colleagues of the early childhood teachers in the intervention group. It can be assumed that this is a biased group of teachers with a high interest in early mathematics education. Furthermore, we cannot count out that the early childhood teachers of the intervention group and the control group exchanged information related to the continuous professional development course. In a follow-up study, we would add a second control group with another intervention so that all effects can be directly related to the course design of *EmMa*. Another limitation of our study are the chosen instruments used to measure the mathematics-related knowledge and beliefs. Although these instruments have proved to be valid for pre-service early childhood teachers (Blömeke, Jenßen et al., 2015), they have never been used for in-service early childhood teachers before. Deepening studies should investigate the fit of these instruments critically and develop, if necessary, different instruments that take the experience of the participants into account.

Nevertheless, the results of this study indicate that the continuous professional development course *EmMa* was successful in supporting first steps in early childhood teachers' mathematics-related competence development. The course increased early childhood teachers' mathematical pedagogical content knowledge and decreased their static orientation towards mathematics. No effects could be measured concerning the mathematical content knowledge and teachers' process orientation towards mathematics in general. These results reflect the central idea of the continuous professional development course to "[f]ocus on making small changes guided by a consistent, coherent, grand vision" (Sarama and DiBiase, 2004, p. 439). Although *EmMa* is guided by the vision to foster a broad mathematical understanding and both, mathematical content knowledge and mathematical pedagogical content knowledge are discussed, the course focuses mainly on aspects of mathematical pedagogical content knowledge. Bearing in mind that our participants had nearly no experience with mathematics education in their teacher training it can be seen as an important result that early childhood teachers' mathematical pedagogical content knowledge can be fostered - in general, but also through continuous professional development. Thus, together with previous research our results give reason to argue for a greater emphasis on the development of early childhood teachers' mathematical pedagogical content knowledge in education and training.

Looking at mathematical content knowledge, the data analysis shows no development. This result is likely to be related to the test instrument we used. Mathematical content knowledge did indeed play a major role in the continuous professional development course; however, this was mainly mathematics used in the context of early mathematics education (explicit knowledge as described by Gasteiger & Benz, in press). The test we used (Blömeke, Jenßen et al., 2015) was in fact developed for early childhood teachers, but measures mathematical content knowledge at a secondary school level. This might not be the appropriate level to measure early childhood teachers' knowledge. Thus, a possible development in mathematical content knowledge more closely related to early childhood education and therefore addressed in the continuous professional development might not have been detected. Follow-up research should measure mathematical content knowledge in a way that is more closely related to early childhood education and takes the different knowledge representations of early childhood teachers into account (see also Gasteiger & Benz, in press; McCray & Chen, 2012; Oppermann et al., 2016).

Regarding the decrease of the static orientation, it can be assumed that this result can be lead back to the experiences of the participants in problem solving and argumentation offered during the continuous professional development course. *EmMa* emphasises that mathematics is not only calculating but also problem solving and communicating with others about individual solutions. This is also supported by statements of the participants in a group interview that was conducted at the end of the continuous development course: e. g., "I can remember at the first day, I believe, at the first questionnaire there was also the question "Is mathematics fun?" And there I was like "hmmmmmm, well" (laugh), but math is really not just learning equations and operations and arithmetic. It is much, much, much, much, much more and for that, we sharpened our awareness. And I thought that was really nice."[2] At this point, further research is necessary to detect *how* the participants changed their beliefs.

The process-related orientation has not changed in both groups. This could be due to the high agreement on this scale in the pre-test but it could also indicate that it needs more time as well as even more experiences with mathematics to support the process orientation (Benz, 2012). Furthermore, earlier studies with teachers found beliefs to be comparatively stable (e.g., Grigutsch et al., 1998). Looking at the application orientation it probably needs a different measurement as the scale we used revealed a ceiling effect at the beginning of the intervention. Taken together, the results concerning the beliefs of early childhood teachers towards mathematics in general show that early childhood teachers do think that mathematics is applicable in everyday life and is an activity to solve problems rather than an abstract structure. Furthermore, the results give reason to argue that a change in beliefs based on professional development is possible.

Looking ahead, effects of *EmMa* on other than the mentioned competence facets would be interesting. Based on the research results on the relationships between the competence facets (Figure 1) it seems reasonable to assume that also the situation-specific skills (perception and decision-making) are influenced by *EmMa*. Furthermore, previous research of McCray and Chen (2012) reported a direct effect of the mathematical pedagogical content knowledge on the mathematical skills of the children. Hence, an effect of *EmMa* on the child level could be possible. Here, further studies are necessary. Finally, yet importantly, further research is needed to look at possible long-term effects of the continuous professional development course.

Conclusion and Outlook

With our continuous professional development course *EmMa* we tried to develop an opportunity for in-service early childhood teachers to learn about early mathematics in kindergarten. Our intervention study showed that the course has been a learning opportunity for many early childhood teachers that took part in it. The participants enhanced their knowledge about fostering mathematical literacy in informal and formal settings, development of mathematical literacy and about analysing and promoting early mathematical skills. This gives reason to claim that it is possible to foster in-service early childhood teachers' mathematical pedagogical content knowledge in continuous professional development courses. In addition, our results support the assumption that a change of beliefs is possible through appropriate and meaningful learning opportunities. Although our participants have shown a much more process-oriented understanding of mathematics than expected, improvements could still be made concerning their static orientation. Nevertheless, we also learned that early childhood teachers already believe that mathematics is useful for their everyday life and that they hold static and process oriented beliefs

[2] The statement was translated by the authors.

at the same time. This is a phenomenon, which could so far only be discovered for early childhood educators (Blömeke, Suhl, & Döhrmann, 2012; Dunekacke et al., 2016). Lastly, but most importantly, our study resulted in a course concept that proved to be effective to support the competence development of early childhood teachers in the fields of early mathematics education. Based on this concept further efforts can now be made to bridge the gap between pre-service education with nearly no mathematical content and the challenges early childhood teachers face in practice concerning early mathematics education. Next, a more systematic approach to support early childhood teachers in fostering early mathematical learning in kindergarten has to follow. This means that more early childhood teachers in Germany should get the opportunity to take part in this or a similar continuous professional development course. Our first step in this direction is to build up a multipliers program, called *EmMa*[M]. In this program, we would like to pass on our materials, our knowledge and our experience to trainers so that they can again support other early childhood teachers in fostering mathematical learning in their kindergarten. In the long term, this gives us a way to create a sustainable professional development that supports a large number of early childhood teachers in the development of their mathematics-related competence.

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