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Effects of Facilitator Professional Development on Teachers' Learning – An Intervention Study in the Context of Early Mathematics Education

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A fundamental question in the context of professional development is whether teacher professional development (TPD) can be scaled up successfully using facilitator professional development (FPD) programs. Studies that link effects of FPD programs to teacher learning are, however, rare. The presented study addresses this research gap by examining effects of an extensive FPD program in the context of early mathematics education ($EmMa^M$). To examine effects of $EmMa^M$, a quasi-experimental intervention study with two intervention groups was conducted: While in group A the TPD course was enacted by the program developers, in group B the TPD was enacted by facilitators. Results show that teachers in group B achieved comparable learning gains to teachers in group A. This result supports the idea of scaling up professional development using FPD – if facilitators are qualified accordingly.

Keywords: Facilitator professional development, in-service professional development, teacher learning, early mathematics education.

Facilitator Professional Development Programs and its Effects

Teacher professional development (TPD) is essential to improve teaching quality and support teachers' lifelong learning (e.g., Borko, 2004). Therefore, a shared aim of school administration, developers of professional development (PD) programs, and researchers is to scale up effective PD programs (e.g., Roesken-Winter et al., 2015). This scaling up can be realized by qualifying facilitators to enact TPD at several sites (Borko, 2004). To support facilitators in their (new) role, several authors suggest facilitator professional development (FPD) programs which include PD materials and activities for teachers as well as support materials for facilitators to enact the PD program (Borko, 2004; Koellner et al., 2011; Prediger et al., 2019).

Prediger et al. (2019) developed the *Three-Tetrahedron Model of professional development* "to capture the complexity of PD courses in a multifaceted way and to connect the different levels of (1) teaching and learning on the classroom level, (2) PD on the teacher level, and (3) PD on the facilitator level" (p. 408). The *Three-Tetrahedron Model of professional development* suggests a cascadic approach to scale up PD programs. In cascade models a group of facilitators, who are mostly teachers themselves, is trained to conduct TPD programs (Krainer, 2015).

Different authors question the effectiveness of cascade models: They criticize that cascade models follow a transmissive approach and do not take the context of the individual facilitator into account (e.g., Hayes, 2000; Kennedy, 2014). Additionally, for example Krainer (2015) expects a dilution of

expertise with each level of the cascades. In summary, it is assumed, that facilitators might have less developed mathematical expertise and/or less accomplished facilitation practices then their trainers which in turn leads to less expertise at the teacher level. Whether this is the case has yet to be examined.

Therefore, a key question is whether TPD programs enacted by facilitators in FPD programs achieve effects on teachers' learning (Koellner et al., 2011; Perry & Boylan, 2018; Prediger et al., 2019; van Driel et al., 2012). The few research results on the effects of FPD on teachers' learning available in the field of mathematics education indicate that teachers that were trained in a PD course enacted by facilitators increased their knowledge in comparison to untrained teachers (Bell & Higgins, 2010), but show less competence than their facilitators (Koellner & Jacobs, 2015; Lange, 2014; Turner et al., 2017). Additionally, effects of TPD differ with respect to the facilitator (Bell & Higgins, 2010; Carney et al., 2019). In summary, these results support the assumption that the scaling up of TPD using FPD is possible. However, the results do not clarify the extend of these effects and thus do not address the criticism of the dilution of effects with each level of the cascades. This is especially true as there is a lack of research comparing the effects of TPD courses enacted by facilitators (i.e. the originators/developers of the PD courses). The present study starts out to address the questions of the dilution of effects with each level for the dilutions of the dilution of eacher study starts out to address the questions of the dilution of the cascades by examining FPD in the context of early mathematics education exemplified by the FPD program $EmMa^M$ (Bruns et al., 2021).

The Context of this Study: $EmMa^M$ – A FPD Program for Early Mathematics Education

A key feature of the *Three-Tetrahedron Model* is to base FDP on TPD. To realize this, we firstly developed a TPD course on early mathematics education called *EmMa - Erzieherinnen und Erzieher machen Mathematik* [EmMa – Early childhood teachers are doing mathematics] (Bruns et al., 2017), secondly examined the effectiveness of this TPD course (Bruns et al., 2017) and thirdly developed the facilitator professional program $EmMa^M$ (Bruns et al., 2021). The development of the facilitator professional program $EmMa^M$ (Bruns et al., 2021). The development of the facilitator professional program $EmMa^M$ (Bruns et al., 2017; Koellner et al., 2011; Schifter & Lester, 2005):

- Considering all aspects of teaching and learning on the teacher and the classroom level: To realize this first key feature, the structure and content of the FPD program *EmMa^M* is based on the structure and content of the TPD course *EmMa*. *EmMa^M* comprises of an introductory module and four in-depth modules which each lasts two days. Additionally, *EmMa^M* integrates various activities from the TPD course *EmMa*, which are firstly carried out by the facilitators themselves and afterwards reflected on with regard to the aims of the activities. *EmMa^M* thereby addresses the content of the TPD course *EmMa* from a higher level which also includes typical teacher misconceptions and reflection of teaching strategies.
- **Integrating and modeling activities of the teachers PD program**: As all activities as well as all theoretical aspects from the modules of the TPD course *EmMa* are enacted by the leaders of the FPD course, these leaders also function as a model for the facilitators.

- Supporting the preparation, implementation as well as the follow-up of the TPD course: In practical phases between the FPD modules, the facilitators independently lead TPD courses on early mathematical education. Through these practical phases, *EmMa^M* realizes an accompanied implementation of the TPD program as advised by Jacobs et al. (2017). Facilitators are supported in the preparation, implementation and follow-up of their TPD course during the FPD.
- Offering supporting materials to enable facilitators to conduct the PD course in alignment with the intended goals of the PD program: The fourth key feature of supporting materials is realized by a set of guiding materials. These materials include suggestions for the methodical structuring of the TPD course, a commented set of presentation-slides for each TPD module and templates for several teacher activities. In addition, the leaders of the FPD provided further literature as well as a set of games and play materials used to foster early mathematical learning in kindergarten (games, pattern blocks, etc.) which is used to plan different learning opportunities for children in the TPD program.

All in all, the FPD program extends over a period of 10 months and includes 85 hours of presence time and at least 100 hours of time to prepare and implement the TPD course in the practical phases.

Design of the Study

Research Question and Research Approach

To examine effects of *EmMa^M*, a quasi-experimental intervention study with two intervention groups was conducted: While in group A the TPD course was enacted by the program developers (first author of this paper and a colleague), in group B the program was enacted by facilitators. According to the aims of our study and the TPD course *EmMa*, we focus on the effects on teachers' mathematical pedagogical content knowledge (MPCK) and their beliefs. The leading research question is: Are there significant differences in the development of early childhood teachers' MPCK and beliefs between early childhood teachers that undertook the PD course EmMa enacted by facilitators in comparison to early childhood teachers that visited the PD course EmMa enacted by experts (the program developers)?

Sample

The sample of the experimental group A, the expert group, comprises of n = 76 early childhood teachers (n = 65 female, n = 4 male, n = 7 missing) that visited a TPD course *EmMa* on early mathematics education enacted by the program developers between 2014 und 2016. The early childhood teachers were between 24 and 59 years old, on average 43.97 years (*SD* = 10.81). All early childhood teachers were trained at vocational schools and were working in Germany.

The sample of experimental group B, the facilitator group, comprises of n = 83 early childhood teachers (n = 76 female, n = 7 male) that visited a TPD course *EmMa* on early mathematics education enacted by nine different facilitators. The early childhood teachers visiting these TPD courses were between 21 and 62 years old, on average 42.27 years (SD = 11.08). The early childhood teachers were also trained at vocational schools and are working in five different federal states with comparable frameworks concerning early childhood education.

The developer of the *EmMa* program leading the TPD courses of experimental group A are the first author of this paper, currently a junior professor for mathematics education and a colleague, who is an early childhood teacher himself and currently professor for early childhood education. The nine facilitators leading the PD courses of experimental group B were all visiting the FPD program $EmMa^{M}$. The TPD courses were conducted as a part of this FPD program (practical phase) in 2018. The facilitators were between 31 and 57 years old, in average 43.33 years (SD = 9.83). Six facilitators were trained as early childhood teachers themselves and had between 11 to 30 years practical experience as an early childhood teacher. The other three facilitators had a Master's degree in educational studies, one with mathematics as a major field of her studies. Yet, none of the facilitators had been significantly involved with early mathematics education during their training or studies. Most of the facilitators (7 out of 9) additionally reported prior experience in leading PD courses to different topics relevant to early childhood teaching (e.g., language and literacy) but not to early mathematics education. Experience in PD ranged between 3 to 300 days (M = 70.13; SD = 101.42).

As described facilitators were supported intensively in these practical phases by the leaders of the FPD program. In addition, results of a qualitative study on these practical phases of $EmMa^M$ using the same sample showed that facilitators all stayed very close to the suggestions for the methodical structuring of the TPD course (Bruns et al., 2021). From this it can be followed, that the TPD courses visited by the early childhood teachers in experimental group A and B were comparable concerning content and structure but not necessarily concerning the thematic depth and mathematical correctness.

Instruments

Early childhood teachers' MPCK was measured by a standardized Rasch-scaled test consisting of 35 items (Blömeke et al., 2015). Each item on MPCK was coded dichotomously (0 = not correct/ not reached; 1 = correct). The Rasch scaling model was applied to the coded data. The z-standardized early childhood teachers' WLEs are used as performance values for any further analyses. In our study, the test showed an EAP reliability¹ of .58 which is comparable to earlier studies (ibid.).

The beliefs towards mathematics in general were assessed by a questionnaire (Blömeke et al., 2017) using 27 items and a 6-point Likert scale. The items distinguish five beliefs facets: (1) a static orientation towards mathematics (7 items, Cronbach's α =.83, (2) a process-related orientation towards mathematics (4 items, Cronbach's α =.82), (3) an application-orientation towards mathematics (6 items, Cronbach's α =.80), (4) gender stereotypes regarding mathematics (5 items, Cronbach's α =.92) and (5) enjoyment of mathematics (5 items, Cronbach's α =.87). Every single item ranges from 1 to 6, mean scores have been computed for the different scales. Higher scores indicated that participants had a higher agreement in the mathematics-related statements.

¹ When calculating IRT reliability using Rasch modeling, each participant is assigned an estimated ability value expressed as a score distribution. The predictive reliability is 1 minus the ratio of the variance of a participant's score distribution relative to the sample variance. EAP represents the mean of such predictive reliabilities in the sample and is thus a measure of the overall reliability of the sample that can be interpreted similarly to Cronbach's α (see e.g., Neumann et al., 2010).

Procedures and Analysis

Data on experimental group A was collected in TPD courses led by the program developers in the years 2014 to 2016. Due to missing data, we have 54 (MPCK) respectively 49 (beliefs) complete data sets for the analysis in group A. The facilitators started their FPD program $EmMa^M$ in March 2018. As a part of this FPD program the facilitators lead one EmMa TPD course with 10 to 12 early childhood teachers in the practical phases (see Figure 1). The early childhood teachers visiting these EmMa TPD courses led by the facilitators in training form experimental group B. Due to missing data, we have 82 (MPCK) respectively 81 (beliefs) complete data sets for the analysis in group B.



Figure 1: Interconnections between the TPD enacted by the program developers (group A), the FPD and the TPD enacted by the facilitators (group B)

In order to assess whether the early childhood teachers' MPCK and mathematic-related beliefs changed from measurement point 1 to measurement point 2, we used a t-test for dependent samples. Based on these findings, for each competence facet a repeated measure ANOVA was used to determine the extent to which changes differ depending on the experimental group. The absence of significant differences would indicate comparable effects in both groups.

Results

The results of a paired t-test confirm significant increases in MPCK for both groups. The early childhood teachers from experimental group A score a mean of 46.81 points on the pre-test for measuring the MPCK and a mean of 49.89 points on the post-test (t(53) = -3.03, p < .01, d = 0.26). The early childhood teachers from experimental group B score a mean of 47.39 points on the pre-test for measuring the MPCK and a mean of 50.21 points on the post-test (t(81) = -2.23, p < .05, d = 0.27). The results of the repeated measure ANOVA reveal a significant main effect of the measurement point (p < .01, $\varepsilon^2 = .08$) but not of the experimental group. There was also no interaction effect. In other words, early childhood teachers in both experimental groups increased their MPCK equally.

Concerning the beliefs, the results of paired t-tests confirm significant increases in the agreement to process (EG A t(48) = -2.16, p < .05, d = 0.30; EG B: t(81) = -4.41, p < .001, d = 0.50) and application orientation (EG A: t(48) = -4.41, p < .001, d = 0.55; EG B: t(81) = -3.07, p < .01, d = 0.40) statements towards mathematics and in the agreement to statements concerning the enjoyment of mathematics (EG A: t(48) = -5.37, p < .001, d = 0.76; EG B: t(81) = -6.28, p < .001, d = 0.78) for both experimental groups. Furthermore, significant decreases in the agreement to static orientation statements towards mathematics (EG A: t(48) = 6.73, p < .001, d = 0.86; EG B: t(81) = 6.45, p < .001, d = 0.78) and in the agreement to gender stereotypes (EG A: t(48) = 4.69, p < .001, d = 0.58; EG B: t(80) = 4.60, p < .001, d = 0.42) statements regarding mathematics are also confirmed for both experimental

groups. The results of the repeated measure ANOVA reveal significant main effects of the measurement point but no main effects of the experimental group. There are also not given any interaction effects. In conclusion, early childhood teachers in both experimental groups succeeded equally in positively changing mathematics-related beliefs.

Discussion

Limitations of the study

Our study bears limitations regarding the sample of early childhood teachers in the two groups. The TPD courses in group A and B were time-shifted by about three years. We did, however, find no differences between the groups on the pre-test scores and therefore concluded that the differences in the sample seem to be neglectable for this study. Secondly, limitations can be traced back to the instruments used to measure early childhood teachers' mathematical pedagogical content knowledge. To compare the facilitator and the expert group regarding their learning effects, we used the same instrument to measure teachers' mathematical pedagogical content knowledge (Blömeke et al., 2015). The test score interpretation of this instrument is, however, validated for a sample of pre-service not in-service teachers and the test instrument follows a rather cognitive and broad approach regarding mathematical pedagogical content knowledge. Further limitations occur concerning the sample of the facilitators. This group was very heterogenous regarding their education, experience with TPD in general and their experience with mathematics and mathematics education (in early childhood settings). Likewise, it should be mentioned that facilitators followed the suggested structure, content and activities of the TPD course *EmMa* quite closely (Bruns et al., 2021). It can therefore be assumed that the effects we found can partly be attributed to the concept of the TPD course *EmMa*.

Interpretation and Conclusion

To our knowledge this is the first study that addresses the criticism of expertise dilution with each level of the cascades by comparing effects of TPD courses enacted by facilitators to effects of TPD courses enacted by experts in the field. As did previous research (Bell & Higgins, 2010; Carney et al., 2019; Koellner & Jacobs, 2015; Lange, 2014; Turner et al., 2017), our study found that TPD courses enacted by facilitators can achieve effects on teachers' learning concerning their MPCK as well as their beliefs – if facilitators are qualified accordingly for the job and supported by experts in the field. Adding to the state of research, our study found that these effects are comparable to effects of experts in the field. Our study did not indicate any differences in the effects of the TPD course between the expert group and the facilitator group regarding the development of teachers' MPCK nor their mathematics-related beliefs. This result supports the idea of scaling up PD using FPD (Borko, 2004; Koellner et al., 2011; Prediger et al., 2019) as it reveals that experts and facilitators can achieve the same effects on teachers' learning through TPD.

However, this result must be considered in the light of the FPD concept: The effects found in this study are not only based on quality of the TPD courses lead by the facilitators and the expertise of the facilitators, but also on the extensive resources and specific materials used to support facilitators in leading TPD courses (s. a. Borko, 2004; Koellner et al., 2011; Prediger et al., 2019). It can therefore not be ruled out that there is a dilution of expertise with each level of the cascades. In fact, in an accompanying qualitative study, we found that the facilitators make a lot of incorrect statement during

their TPD courses (Bruns et al., 2021). Our results of this study do, however, indicate that this lack of expertise can be compensated by the close monitoring of the facilitators and the high quality of the TPD resources. Our results therefore support those critical perspectives on the cascade model that direct their criticism towards the implementation of the cascade model in practice (Hayes, 2000; Wedell, 2005). Still to be investigated is the extent to which the effects of the TPD courses differ depending on the facilitator (see also Bell & Higgin, 2010; Carney et al., 2019). Nevertheless, we conclude from this that scaling up TPD by qualifying facilitators to enact TPD at several sites can be successful – but probably has to be accompanied not only by extensive facilitator training but also high-quality resources to facilitate the TPD.

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