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Enhancing and analyzing kindergarten teachers' professional knowledge for early mathematics education

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ABSTRACT

While early childhood mathematics education did not play an important role for many years, today the necessity to be attentive to children's early mathematics learning is no longer in doubt. There is a broad consensus that mathematical learning in kindergarten is more informal than learning in school. To guarantee coherent mathematical learning in kindergarten, pre- and in-service education of kindergarten teachers in mathematics education is becoming more important. Therefore, a sound theoretical foundation and examination of professional knowledge to realize early mathematics education are necessary. We present a theoretically and empirically founded domain-specific model of kindergarten teachers' professional knowledge. It serves as a framework to plan and realize professional development programs – as an example shows. A qualitative study – worked out in the German context – indicates that this structure can help to analyze kindergarten teachers' professional knowledge. We indicate how our findings and interpretations connect to issues shared across national contexts.

1. Introduction

While the necessity of mathematical learning in kindergarten and pre-school-settings is more and more stressed in the scientific field of mathematics education, early mathematics education still plays a less significant role in pre-service training of kindergarten teachers (Ginsburg, 2016; Kucharz et al., 2014). Respecting this situation demands the development of pre- and in-service programs for kindergarten teachers in early mathematics education, based on a sound theoretical foundation from a mathematics education perspective (Polly et al., 2017; Sarama & DiBiase, 2004). Due to the facts that early mathematics learning in kindergarten is much more informal than learning in school and kindergarten teachers usually do not have the same mathematical content knowledge as elementary teachers (at least in some countries), not everything that works in professional development of elementary teachers may work in professional development of kindergarten teachers (Sarama, Clements, Wolfe, & Spitzer, 2016). Designing professional development programs for kindergarten teachers requires analyzing and considering all components of professional knowledge and skills which are necessary to realize early mathematics education successfully. To guarantee that efforts of professional development are effective, it is necessary to evaluate these programs. Therefore, we need criteria and categories that help to identify development and improvement in kindergarten teachers' professional knowledge and skills.

In this contribution, a domain-specific model of kindergarten teachers' professional knowledge and skills for early mathematics education is presented (Section 3), which describes facets of professional competence and relations between these facets. Referring to this model, programs to enhance professional knowledge of kindergarten teachers can be planned and realized. An assumption is that

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this model can as well serve to analyze kindergarten teachers' professional knowledge in the different relevant facets precisely. The concept of a combined pre- and in-service course for kindergarten teachers shows exemplarily how the different facets of professional competence described in the model can be addressed in a professional development program and first results indicate the suitability of the model for a profound analysis of kindergarten teachers' professional development (Section 4).

2. Mathematical teaching and learning in early childhood education

Designing programs to enhance kindergarten teachers' professional knowledge for early mathematics education requires a theory-based analysis of the job a kindergarten teacher has to do. Only then, all the facets of competence he or she needs could be clarified (Blömeke, Gustafsson, & Shavelson, 2015) and in consequence could be addressed in professional development programs. This job-analysis must be set up on well-founded ideas about mathematical contents as well as about how to organize and structure mathematics education at this age, because e.g. instructing in form of designed lessons or a given curriculum would demand different skills from kindergarten teachers than acting and reacting spontaneously in rather informal mathematical learning situations.

In the last decade theoretical analysis and empirical results helped to deduce some cornerstones or principles on how to implement a high-quality early mathematics education. Meantime, these principles are widely accepted in different countries and they can be found in official statements, handbooks of mathematics education or publications for kindergarten teachers or even for parents (e.g. Benz et al., 2017; Brownell et al., 2014; Gasteiger, 2012; Ginsburg, Lee, & Boyd, 2008; Hunting, Mousley, & Perry, 2012; Van den Heuvel-Panhuizen, 2001). These principles will be explicated as a foundation to analyze which professional knowledge kindergarten teachers need.

First, there is a broad consensus that the content of early mathematics education learning offers should focus on central, fundamental ideas of mathematics (Brownell et al., 2014; Sarama & Clements, 2009). To facilitate children's mathematical learning in school, the mathematical content in early mathematics education must be presented mathematically correct. Though mathematical correctness seems to be a matter of course, there are some examples of training or learning programs for early mathematics education, where mathematical correctness got lost because of the transfer of mathematical ideas to an elementary level (Krajewski, Nieding, & Schneider, 2007; Preiß, 2006; detailed analysis in Gasteiger, 2010) or because of a very narrow range of a mathematical content (Ginsburg et al., 2008).

A further principle relates to the organization and design of mathematical learning processes at elementary level. All efforts of early mathematics learning should guarantee that children can engage in creative and challenging tasks (Seo & Ginsburg, 2004) which enable them to learn problem-solving strategies and to discuss mathematical ideas. Hence, narrowly guided and instructive lessons do not seem to be appropriate for early mathematical learning. Psychological findings support this claim, because children at kindergarten age may have difficulties benefiting from learning lessons as they are normally practiced in school contexts (Hasselhorn, 2005). Therefore, using "natural learning situations" (Gasteiger, 2015, p. 258), like playing as a child-oriented activity or using everyday situations (e.g. setting the table, time schedule), is considered productive for early mathematics education (Gasteiger, 2015; Ginsburg et al., 2008; Hirsh-Pasek, Golnikoff, Berk, & Singer, 2009; Van Oers, 2010). Using natural learning situations for mathematical learning does not mean to be satisfied as a kindergarten teacher, if children learn mathematics more or less by chance in some situations. It means to support children's mathematical development with "artful guidance" (Greenes, cited by Seo & Ginsburg, 2004, p. 103), goal-oriented and consciously to bring their experiences "into a fuller and richer and also more organized form, a form that gradually approximates that in which subject matter is presented to the skilled, mature person" (Dewey, 1938, p. 48).

Therefore, it is a crucial part of early mathematics education, to observe and document children's learning processes thoroughly. Only if children's individual abilities and steps of learning are recognized, it is possible to encourage their further learning and to foster their mathematical development adequately (Bruns, 2014; Ginsburg, 2016; Nguyen et al., 2016; Peter-Koop & Grüßing, 2014). This applies to all children but it has a special meaning for children at risk – those with less mathematical knowledge than their peers. With a subject-oriented diagnostic look, special needs can be recognized and the kindergarten teacher can support children at an early stage in achieving a sound foundation for mathematics learning at school (Clarke, Gervasoni, & Sullivan, 2000; Krajewski & Schneider, 2009; Peter-Koop & Grüßing, 2014).

These demands on early mathematics education, which have been deduced from theoretical aspects, show a broad range of knowledge, skills and competencies kindergarten teachers need to implement high-quality early mathematics education. Kindergarten teachers should, for example, plan learning opportunities and spontaneously encourage mathematically-based learning processes in situation-dependent contexts. In doing so, they should show a sensitive situational perception in order to identify mathematical learning opportunities, consider the mathematical development of all children and react with appropriate stimuli. All efforts of early mathematics education should respect mathematical correctness. These requirements would lead to a very complex structure of professional competence, which must be solidly substantiated and analyzed.

3. Kindergarten teachers' professional knowledge and skills for mathematics education

Based on findings about mathematics-related teacher knowledge (Ball, Thames, & Phelps, 2008; Blömeke, Kaiser, & Lehmann, 2010; Lindmeier, 2011; Shulman, 1987), about the general pedagogical knowledge, skills and competencies of kindergarten teachers (Fröhlich-Gildhoff, Weltzien, Kirstein, Pietsch, & Rauh, 2014) and on empirical results about various relationships between different facets of mathematical competencies of kindergarten teachers (Anders & Roßbach, 2015; Dunekacke, Jenßen, & Blömeke, 2015; Dunekacke, Jenßen, Eilerts, & Blömeke, 2016; Lee, 2010; McCray, 2008), a model of kindergarten teachers' professional knowledge

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