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What do vocational school teachers in the field of early childhood education plan for their early mathematics education classes? – An analysis of hypothetical lesson plans on early numeracy

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As the initial training of early childhood (EC) educators becomes more relevant, there is a growing discussion on how to integrate early mathematics education in EC educators' initial training. To gain more insight into early mathematics education within German vocational school training for EC educators we analysed hypothetical lesson plans by vocational school teachers on the topic of early numeracy. The analysis focuses on what content was included and what competencies of the prospective EC educators were addressed. The results show that not all vocational teachers plan meaningful learning opportunities for EC educators and allow some implications for the professional development of vocational school teachers teaching early mathematics education.

Keywords: Early mathematics education, lesson planning, vocational school training.

Introduction

Due to the growing interest in early mathematics education, the initial training of early childhood (EC) educators (i.e., professionals working with children aged 0 to 6) becomes more relevant, and there is a growing discussion on how early mathematics education should be integrated in EC educators' (initial) training (Dunekacke & Barenthien, 2023; Whyte et al., 2018).

Whyte et al. (2018) interviewed professionals involved in both, pre-service and in-service training of EC educators about how they include early mathematics education in their teaching. The study found that their interview partners try to relate themes of early mathematics education to the context of EC education. In addition, professionals involved in the training of EC educators stress a conceptual understanding of the mathematical concepts integral to early mathematics education with a focus on numbers and counting. Regarding the teaching activities, analysing and developing learning material and activities, as well as the use of videos from early educational contexts seem to be most present (Whyte et al., 2018). Dunekacke and Barenthien (2023) found correlations between the frequencies of learning opportunities in the field of early mathematics education in EC educators' initial training and the teaching experience of their teachers. This state of research gives a first insight into the teaching of early mathematics education in EC educators' (initial) training, but is still limited as it is based exclusively on interviews or surveys. Our study starts out to extend these findings by focusing on the lesson planning on early mathematics education in the initial training of EC educators and thereby offering a more practice-related insight into the teaching of early mathematics education in EC educators' (initial) training.

In Germany, this initial training takes place in vocational schools (Dunekacke & Barenthien, 2023). Typically, prospective EC educators are between 18 and 22 years old and complete their training in three years, which often integrates various forms of practical internships. Vocational school teachers are responsible for designing lessons on, e.g., how to support children's learning of numeracy (Dunekacke & Barenthien, 2023). Vocational school teachers are trained at universities and, as they

teach prospective EC educators, they are also teacher educators. However, similar to other countries (Whyte et al., 2018), they are rarely trained explicitly to teach early mathematics education, but rather in the subjects of either social sciences or mathematics (Dunekacke & Barenthien, 2023).

Therefore, we want to take a closer look on how those vocational school teachers plan lessons on early numeracy for prospective EC educators by asking: What content and what competences do lesson plans on early numeracy by vocational school teachers emphasise for prospective early childhood educators in the context of early mathematics education?

Literature Review

Teaching early mathematics education to prospective EC educators is highly related to what EC educators need to learn to support young children in their development of early numeracy. This includes two aspects, which are described in the following two sections: (1) competences of EC educators in the field of early mathematics education and, (2) the mathematical concepts that children need to learn, and thus, should be the subject of EC educators' training.

Competences of early childhood educators in the field of early mathematics education

Starting from the informal and play-based nature of many preschool contexts, Gasteiger and Benz (2018) developed a domain-specific model based on international frameworks of and research on EC educators' competence. This model gives insights into what knowledge, skills and competences prospective EC educators should develop in the field of early mathematics education. Following Gasteiger and Benz (2018), EC educators' math-related competence includes:

- *Explicit knowledge* about which mathematical concepts are relevant for young children in light of the continuity of mathematical learning, about the developmental process of early mathematical skills (e.g., counting), and about learning material. This competence facet therefore includes mathematical content knowledge as well as mathematical pedagogical content knowledge relevant to the preschool context.
- *Situational observing and perceiving* refers to the ability to spontaneously recognise mathematical relevance in different situations (e.g., play situations or everyday situations) as well as in actions and utterances of children.
- *Pedagogical and didactical action* means to design planned learning activities as well as to spontaneously implement learning opportunities according to the needs of the children.
- *Reflection and evaluation* on past observations and interactions to further develop their knowledge as well as their beliefs.
- *Attitude, beliefs and motivation* influence if and how EC educators perceive mathematical learning opportunities as well as if they are able to act on them effectively.

As research has shown a significant relationship between EC educators' opportunities to learn in their initial training and their development of math-related competence (Blömeke et al., 2017; Dunekacke et al., 2021), it seems advisable for vocational school teachers in the context of EC educators' initial training to already address each of these competence facets in their lesson planning. Moreover, research shows a close interrelation between these competence facets (e.g., Dunekacke et al., 2016; Leavy & Hourigan, 2016) which might indicate that the competence of EC educators is also specific

to mathematical sub-domains relevant to the preschool context (e.g., early numeracy). In this study, we focus on the sub-domain of early numeracy.

Early numeracy in early mathematics education

Related to early numeracy in EC educators' initial training, Leavy and Hourigan (2016) argue that EC educators need to develop a deep understanding of the connections between the mathematical concepts that children need to learn. Only then EC educators can, for example, support the individual children in their development of early numeracy appropriately. In the following, we briefly describe the mathematical concepts that children need to learn in the sub-domain of early numeracy, and, thus, should be subject in EC educators' initial training.

For once, children need to understand that numbers can mean different things in different contexts (e.g., aspects of cardinality, ordinality) (e.g., Clements & Sarama, 2021). Next, a solid conceptual understanding of numbers and quantities is key, which includes subitizing and quasi-subitizing, one-to-one correspondence, part-whole concept, and comparing quantities (e.g., Clements & Sarama, 2021; Resnick, 1992). For example, one-to-one correspondence needs to be understood to count a set of objects correctly by assigning each object to a different number word (Gelman & Gallistel, 1978). Besides one-to-one correspondence, children need to apply all counting principles, as well as the number word sequence correctly to be able to count (e.g., Fuson, 1988; Gelman & Gallistel, 1978). Lastly, children should develop basic concepts of operations, which build on the conceptual understanding of numbers and quantities, as well as counting abilities (e.g., Resnick, 1992).

Methods

Study design and context

Due to the explorative nature of the research question, a qualitative methodological approach was chosen. The data of this study derives from a larger professional development project with vocational school teachers teaching early mathematics education. In the scope of this project, all participating vocational school teachers had to hand in a hypothetical lesson plan on the topic of early numeracy. These hypothetical lesson plans form the data for the presented study. Hypothetical, as they did not need to teach the designed lesson before handing in their planning.

As part of the professional development program, all participating vocational school teachers received educative curriculum material developed for the initial training of EC educators with supplementary self-learning material. This included amongst other things an informational text, suggested lesson plans, presentation slides and videos. Related to early numeracy the curriculum material addresses the following topics:

- Conceptual understanding of numbers (i.e., number aspects, their meaning for mathematics in itself as well as for numbers in an everyday context),
- Conceptual understanding of quantities (i.e., the main concepts and abilities children need to develop when dealing with quantities, such as subitizing and quasi-subitizing, one-to-one correspondence, part-whole concept, comparing quantities and proto-quantitative schemes),
- Counting abilities (i.e., development of the counting sequence, counting principles, typical counting mistakes and the development of counting skills),

- Conceptual understanding of operations (i.e., basic operations of addition and subtraction).

Participants and data material

For the analysis we had a hypothetical lesson plan on numeracy from each of 33 vocational school teachers (28 female). All teachers were between 27 and 63 years old. Their teaching experience varied between 0.5 and 37 years, and they taught prospective EC educators between 1 and 25 lesson units (45 minutes) per week. The participation in the study was voluntary.

Methods of qualitative data analysis

The lesson plans were analysed using deductive as well as inductive methods (Mayring, 2015) in the following steps.

Step 1: To get a clear picture which competence facets vocational school teachers addressed in their lesson planning regarding early numeracy, the lesson plans were coded based on the math-related competence facets by Gasteiger and Benz (2018):

- The code *explicit knowledge* (EK) included theoretical input (e.g., presentations, reading tasks), including knowledge of learning material (e.g., games, picture books) under the prerequisite that only mathematical concepts within the material should be discussed.
- The code *situational observing and perceiving* (SOP) included lesson plan descriptions of activities in which explicit knowledge is spontaneously applied in a given situation. This included, for example, the analysis of videos or role play to diagnose children's mathematical abilities. The analysis of written situations or case descriptions to diagnose children's abilities was excluded from this code, as the character of spontaneity is lost.
- The code *pedagogical and didactical action* (PDA) included lesson plan descriptions of activities as designing mathematical learning opportunities, as well as discussions of how they might be implemented.
- The code *evaluation* (E) included reflections on previous observations and actions (e.g., what counting mistakes they already encountered) as well as on own professional learning experiences.
- The code *attitude, beliefs and motivation* (B) included explicit thematization of prospective EC educators' personal beliefs and attitudes. For example, a scheduled discussion on the personal experiences with mathematics (e.g., as a subject in school).

In addition, all lesson plans were analysed regarding the addressed content in the field of early numeracy. The following codes 1 to 4 were derived deductively and code 0 inductively:

- (0) lesson plan did not specify the covered content,
- (1) conceptual understanding of numbers,
- (2) conceptual understanding of quantities,
- (3) counting abilities,
- (4) conceptual understanding of operations.

Time estimations of the lesson plans in whole, and, if given, for each of their individual elements were recorded.

Step 2: For each lesson plan, an overview over the addressed competences and content was created. These overviews stated information on what content was addressed over the course of one lesson plan and which competences were addressed for which content (e.g., explicit knowledge was addressed for the conceptual understanding of numbers).

Step 3: Each lesson plan was viewed and summarised for what emerged as an emphasis from the written descriptions of each lesson plan (e.g., a certain content such as counting abilities).

Step 4: The lesson plans were systematically compared and contrasted for similarities and differences. By this, groups of lesson plans with a similar emphasis were formed and characterised. The group building relates primarily to the distribution of estimated lesson time and described depth for the addressed competence facets. However, it was also considered how broad (or narrow) content on the topic of early numeracy was covered. As the code *attitude, beliefs and motivation* was not applied to any of the lesson plans at all, it was not included in the group building. By systematically comparing the 33 lesson plans for patterns, we identified six groups of lesson plans.

Results

Two lesson plans form the group “*No relation to early childhood education*”. The lesson plans in this group cover only a narrow selection of content and only in a theoretical way (EK). The selected content either relates to mathematics typically taught in school (by analysing federal state curricula for primary and secondary schools) or higher mathematics (i.e., set theory) without relating to the context of EC education.

Three lesson plans form the group “*Gathering personal experience without theoretical foundation or reflection*”. The lesson plans in this group show little to no building of *explicit knowledge* (EK). Instead, testing material and/or activities and gathering personal experience is emphasised. It remains unclear if the explored material or the activities are reflected on with regard to their mathematical potential or children’s learning opportunities (and hereby addressing PDA and/or E). It is possible that teachers in this group intended to provide prospective EC educators with positive experiences of mathematics by minimizing theoretical input their lesson planning.

Two lesson plans form the group “*Diagnosis*”. The lesson plans in this group focus the competence of prospective EC educators to diagnose competences and abilities of children, which is a sub-facet of *situational observing and perceiving* (SOP). This is realised through the analysis of videos of children in typical play situations. The lesson plans in this group zoom in on a specific subtopic (either the conceptual understanding of numbers or counting abilities). An explicit theoretical input (EK) on the respective content subtopic is given, which consolidates the diagnosis of the children abilities. However, it is not addressed how the diagnosis implicates next steps in guiding or enhancing the children’s learning (PDA and E). The lesson plans show no room for the analysis or development of learning activities (PDA).

Seven lesson plans form the group “*Learning material and activities for children*”. The lesson plans in this group, while in some kind addressing *explicit knowledge* (EK), prioritise the analysis and/or development of learning material (e.g., games, picture books) and activities for children (PDA). For example, in one lesson plan it is mentioned that an informational text with unspecified content should be handed out as a basis for students to develop a learning activity which enhances at least three

different mathematical “aspects” (though it remains unclear what the term “aspects” means here). Lesson plans in this group seem to aim for the students to be able to independently and appropriately analyse, choose and develop learning material or activities. Most of the lesson plans cover a large spectrum of content and only few zoom in on one specific subtopic, in which case they mainly focus counting abilities.

Six lesson plans form the group “*Enhancing conceptual understanding of early mathematics education*”. The lesson plans in this group show an emphasis on the competence facet of *explicit knowledge* (EK) and a deep conceptual understanding of the covered subtopics of early numeracy. Many of those lesson plans cover one singular subtopic (e.g., conceptual understanding of numbers). Lesson plans covering a larger spectrum of content, tend to explicitly connect subtopics to each other (e.g., one lesson plan emphasises the significance of the conceptual understanding of quantities for the conceptual understanding of operations). In this group, the competence facet of *pedagogical and didactical action* (PDA) is not addressed. Some lesson plans address the competence facets of *situational observing and perceiving* (SOP) and/or *evaluation* (E). The descriptions given for the according lesson activities suggest that these activities are meant to deepen the conceptual understanding of the content (e.g., a discussion on typical counting mistakes is enhanced by a reflection on which counting mistakes the students already encountered).

Finally, 13 lesson plans form the group “*Linking theory and practice*”. The lesson plans in this group addressed most competence facets (EK, SOP, PDA and E) and set them into relation between each other. For example, lesson activities as video analysis of children playing (SOP) or the analysis or development of learning material (PDA) are anchored in a theoretical foundation of early mathematics education (EK). Many of the lesson plans incorporate explicit reflection on what the prospective EC educators learned and, prospectively, want to incorporate in their own practice (E). Most of the lesson plans in this group cover a large spectrum of content by evenly distributing time for the subtopics of conceptual understanding of numbers, conceptual understanding of quantities, counting abilities as well as conceptual understanding of operations. Few of the lesson plans in this group emphasise specific subtopics. Those lesson plans focus the conceptual understanding of numbers and counting abilities while the other subtopics are covered only briefly or not at all.

Discussion

In the presented study, we gained insight into what vocational school teachers emphasise in their lesson planning on early numeracy. Our findings closely relate to those of Whyte et al. (2018). Firstly, as in the study by Whyte et al. (2018), a general emphasis on the context of EC education emerged from the lesson plans in our study. Important competences of prospective EC educators are addressed (Gasteiger & Benz, 2018) and the lesson plans, thereby, indicate that EC educators could be prepared appropriately for their future practice. Many of the lesson plans supported the building of deep conceptual understanding of the mathematical concepts involved in early numeracy – as is stressed by Leavy and Hourigan (2016). Though, in some lesson plans the intertwined relationship between these concepts were more obvious addressed than in others. This provides evidence that teachers still need more opportunities for content specific professional development.

Analysing and developing learning material and activities was a common theme in many of the lesson plans. This is similar to the findings of Whyte et al. (2018), where it is summarised as “modeling, coaching or mentoring, and engaging teachers in mathematics activities” (p. 221). Similar to what was described by the interviewed participants in the study by Whyte et al. (2018), many of the lesson plans incorporated videos of typical situations in an early childhood education context. However, in our study such videos were always used for diagnostic purposes, while in the study by Whyte et al. (2018) videos were mainly used as best-practice examples (in a sense of what early mathematics education can look like).

Contrary to the findings of Whyte et al. (2018), some of the lesson plans we analysed left it an open question whether they had the potential to adequately prepare prospective EC educators to support children in their mathematical learning meaningfully. It is possible that the teachers who designed these lesson plans do not (yet) have a clear concept of how to implement early mathematics education in their teaching. These vocational school teachers might need special support to transfer the input of the offered educative curriculum material into their practice.

Some lesson plans were quite narrow concerning the mathematical content covered and/or only estimated a small timeframe for the topic of early numeracy (90-180 minutes). This seems problematic considering previous research pointing out the importance of opportunities to learn on early mathematics education in the initial training of EC educators for the development of their competence (e.g., Dunekacke et al., 2021; Leavy & Hourigan, 2016). The less time is planned within the (initial) training of EC educators for the lessons on early numeracy – or early mathematics education in general – the less opportunities to learn the prospective EC educators receive. However, we cannot derive from our data if the small timeframe was a deliberate choice or due to a perceived lack of time for teaching early mathematics education, which is also described by the professionals interviewed by Whyte et al. (2018).

In sum, this study gives some insight into what content and competence facets in the field of early mathematics education vocational school teachers emphasise in their lesson planning. This is important as opportunities to learn on early mathematics education in the initial training of EC educators are relevant for the development of their competence (Dunekacke et al., 2021). Still, the design of this study does not allow conclusions about what influences the design of lesson plans. We want to stress that the analysed lesson plans only approximate vocational school teachers actual teaching in practice. Teachers might teach in a more nuanced way than is sometimes apparent in their planning. The absence of explicit content input or addressing of certain competences, as for example EC educators’ beliefs, in the lesson plans does not equal their absence in the actual classroom setting. As suggested by Whyte et al. (2018), an analysis of interviews paired with videos of actual lessons would be helpful. Furthermore, it should be investigated, how professional development shapes the lesson planning and teaching of teachers to derive more specific implications for the professional development of vocational school teachers and professionals training EC educators in general.

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