

# All a question of the goal? Re-tracing (mis)alignments between teachers' implementations of curriculum material and intended learning goals in the context of early childhood educator training in Germany

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## ABSTRACT

Curriculum material is often designed to address content-specific intended learning goals. However, research indicates that teachers' personal goals may cause misalignments between their implementation of curriculum material and its intended learning goals. This study aims to investigate misalignments between teachers' implementation of curriculum material and its intended learning goals and to which extent they are caused by teachers' personal goals. To reach this aim, a qualitative study was conducted to examine how eight vocational school teachers implemented the learning activity "How many?" suggested for the initial training of early childhood educators on the topic of set perception and determination of cardinality. Each participant provided a lesson plan and self-recorded lesson video on the topic of set perception and determination of cardinality. In addition, participants were interviewed on how they used the provided curriculum material for designing their lessons and their potential reasons to adapt or omit "How many?". To evaluate their lesson design's alignment with the activity's intended learning goals, the participants' lesson plans were analyzed using qualitative content analysis. Triangulation of the findings with the interview data revealed that only one participant fully adopted the intended learning goals as her own and implemented the activity completely in line with its intended learning goals. Meanwhile, the remaining participants' personal goals, such as reducing math anxiety, seemed to cause misalignments regarding the intended learning goals. The study's results detail further constraints and affordances to the alignment between teachers' lesson designs and learning goals intended by curriculum material. It is followed that it is central to support teachers in adopting intended learning goals as their personal goals. Otherwise, teachers' classroom implementation of curriculum material may not suffice to reach desired outcomes.

**Keywords:** mathematics teacher education research, professional development, curriculum material design, early years mathematics education, content-specific learning goals

## INTRODUCTION

Disseminating curriculum material is a common strategy to implement educational innovation like teacher professional development (PD) or educational reforms (e.g., Ball & Cohen, 1996; Century & Cassata, 2016; Roesken-Winter et al., 2021). To describe "the extent to which an innovation is enacted according to its intended model" (p. 171), Century and Cassata (2016) use the term fidelity of implementation. Curriculum material design typically aims for specific desired outcomes (e.g., Brown, 2009; Davis et al., 2017; Remillard & Heck, 2014). Following Century and Cassata (2016), fidelity of implementation regarding curriculum material is about achieving desired student outcomes defined by content-related learning goals (hereinafter referred to as intended learning goals). Hence, fidelity of implementation does not require one-to-one replication of, for example, a suggested learning activity (Borko, 2004; Century & Cassata, 2016; Cobb & Jackson, 2015; Coburn, 2003; Maaß & Artigue, 2013; Remillard & Heck, 2014). Instead, fidelity of implementation means that teachers design their lessons in a way that aligns with the learning activity's intended learning goals (see also Ahl et al., 2022; Brown, 2009).

Research shows that many teachers struggle to design learning opportunities based on curriculum material that align with the intended learning goals (Brown, 2009; Cevikbas et al., 2024; Leshota & Adler, 2018). Some teachers implement curriculum material without modification but fail to sustain intended learning goals and others create entirely new learning opportunities that appear independent of those suggested in the curriculum material but align with the intended learning goals (Brown, 2009). Thus, a great

variation in what and how content is taught remains a persistent issue (e.g., Morris & Hiebert, 2011). To assist curriculum material designers in effectively communicating intended learning goals, it is crucial to identify factors that afford or constrain sustaining intended learning goals in teachers' implementations of curriculum material (e.g., Brown, 2009; Century & Cassata, 2016; Cobb & Jackson, 2015; Maass et al., 2019).

To do so, this study examines how (vocational school) teachers implement a specific learning activity suggested within the focused curriculum material into their lesson planning. Lesson planning is an integral component of lesson design (see also, Cevikbas et al., 2024; Remillard & Kim, 2017). However, not all of a teacher's intentions are apparent in a written lesson plan (e.g., Remillard & Heck, 2014; Richter et al., 2025). Given that teaching is inherently situational and complex, spontaneous deviations from a prepared lesson plan may occur. Hence, the enactment of the planned lessons was analyzed to evaluate whether teachers' lesson designs align with the intended learning goals. By drawing on teachers' own reflections on their lesson design and their use of the curriculum material, the study also aims to re-trace potential origins of (mis)alignments of the implementations with curriculum material's intended learning goals.

The study takes place in the context of initial vocational school training for prospective early childhood (EC) educators<sup>1</sup> in Germany. In Germany, most EC educators are trained at vocational schools. This setting resembles secondary school education and vocational school teachers are often trained as secondary school teachers (Dunekacke & Barenthien, 2023). As a result, vocational school teachers are usually specialized in two secondary school subjects (e.g., pedagogy and secondary school mathematics) (Dunekacke & Barenthien, 2023). The study's participants are vocational school teachers who teach prospective EC educators how to support young children's development of mathematical competencies. Since early years mathematics education in prospective EC educators' training has gained relevance only recently in Germany, high-quality implementation of curriculum material is most relevant in this context (e.g., Blömeke et al., 2017; Dunekacke & Barenthien, 2023). Many vocational school teachers feel unprepared to teach early years mathematics education for prospective EC educators (Kleeberger & Stadler, 2011). Hence, supporting vocational school teachers in designing meaningful learning opportunities on early years mathematics education for prospective EC educators through curriculum material is crucial. The study thus aims to investigate how vocational school teachers implement curriculum material on the topic of early years mathematics education for prospective EC educators, whether vocational school teachers' implementations of a suggested learning activity align with the intended learning goals and to what extent teachers' personal goals interfere with the alignment.

In the following, Brown's (2009) Design for Enactment (DCE) framework is introduced as a theoretical lens to examine how vocational school teachers implement a suggested learning activity from the EmMa-FS<sup>2</sup> curriculum material. Afterwards, the intended learning goals of the focused learning activity are presented.

## **THEORETICAL LENSES ON VOCATIONAL SCHOOL TEACHERS' IMPLEMENTATION OF CONTENT-SPECIFIC CURRICULUM MATERIAL: THE DESIGN CAPACITY FOR ENACTMENT FRAMEWORK**

In the literature, different kinds of curriculum material can be distinguished (e.g., Davis et al., 2017; Lindmeier et al., 2020). Some kinds are designed to be implemented into the classroom (e.g., worksheets or school books), while others are meant to support teachers in designing their lessons (e.g., background literature, suggested learning activities or lesson plans). The former kinds may support student learning more directly, while the latter may do so either directly (e.g., learning activities) or more indirectly by primarily supporting teacher learning (e.g., background literature). The curriculum material used in this study comprises of both types and is part of the EmMa-FS PD program targeted at vocational school teachers who teach early mathematics education for prospective EC educators. The EmMa-FS curriculum material includes concrete suggested lesson plans and learning activities as well as additional material (e.g., informational texts) to facilitate implementation in line with its intended learning goals.

To examine the complex interaction between teachers and curriculum material, Brown (2009) introduced his Design Capacity for Enactment (DCE) framework. This framework builds on the notion of teaching as design, which is inherently "goal-directed" (Brown, 2009, p. 23). When teachers design a lesson based on curriculum material, they "perceive and interpret existing resources, evaluate the constraints of the classroom setting, balance tradeoffs, and devise strategies – all in the pursuit of their ... goals" (p. 18). Teachers' design choices are, therefore, guided by their personal goals (e.g., Karsenty et al., 2023; Leufer et al., 2019; Prediger et al., 2022; Şahin-Gür & Prediger, 2023; Schoenfeld, 2010; Seidel et al., 2005). At the same time, curriculum material itself conveys intended learning goals by explicitly or implicitly signaling intended uses and outcomes which in turn influences teachers' classroom implementation (Brown, 2009). To neutrally describe how teachers use curriculum material in their lesson design, Brown (2009) uses the neutral terms offloading, adapting and improvising. These three terms act as a scale to describe the degree to which a teacher transfers "agency for guiding instructional activity" (Brown, 2009, p. 24) to curriculum material. When teachers follow, for example, a suggested learning activity (set up, instructional prompts, etc.), they offload instructional agency (almost) completely onto the curriculum material. In contrast, teachers improvise when they diverge from the curriculum material and instead craft their own instructional episodes "with minimal reliance on the materials" (Brown, 2009, p. 24). The term adapting

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<sup>1</sup> EC educators work with children up to six years old prior to school entry. Other terms for this group of professionals include pre-school teachers and EC teachers.

<sup>2</sup> The acronym EmMa-FS stands for "Erzieherinnen und Erzieher machen Mathematik - Fachschule" (Eng.: EC educators doing mathematics - vocational school).

acts as a sort of middle ground between the two ends of this scale to describe when instructional agency distributes relatively evenly between the teacher and the curriculum material (Brown, 2009). Note that these terms do not reflect the alignment of teachers' lesson design with intended learning goals and are not meant to measure fidelity of implementation. Brown (2009) eloquently summarizes this in the following way:

Offloading means using the materials in a literal fashion, but this may or may not result in outcomes intended by the designers of those materials. Similarly, a teacher may improvise in a manner that is perfectly compatible with the goals of the designer or in a way that mutates the original intent.

(p. 25)

Taken together, the DCE framework allows to neutrally describe teachers' use of curriculum material and, simultaneously, normatively evaluate its alignment with the curriculum material's intended learning goals (Brown, 2009). Following Brown (2009), teachers' personal goals drive their use of curriculum material in their lesson design and thereby may afford or constrain the alignment of teachers' implementation with intended learning goals.

Research on teachers' curriculum material use shows that the interaction between teachers and curriculum material relies heavily on interpretation which in turn depends on their own knowledge, skills, beliefs and goals (e.g., Ball & Cohen, 1996; Guedet & Trouche, 2009; Remillard, 2005; Remillard & Kim, 2017) as well as the design of the curriculum material itself (e.g., Brown, 2009; Davis et al., 2017; Prediger & Selter, 2024). Teachers need to unpack intended learning goals in order to design lessons based on content-specific curriculum material that align personal goals with intended learning goals (e.g., Lai & Lam, 2011; Morris et al., 2009).

To normatively evaluate a teacher's ability to, first, unpack intended learning goals and, second, design lessons in alignment with them, Brown (2009) included his conceptualization of Pedagogical Design Capacity (PDC) within the DCE framework. According to Brown (2009), "PDC represents a teacher's skill in perceiving affordances, making decisions, and following through on plans" (p. 29) and "describes the manner and degree to which teachers create deliberate, productive designs that help accomplish their instructional goals" (p. 29). Brown (2009) understands PDC as "an indicator of whether the teacher's designs are pedagogical beneficial" (p. 31). Thus, PDC is closely connected to both, teachers' personal goals as well as curriculum material's intended goals.

Understanding the interplay between teachers' personal goals and curriculum material's intended learning goals seems, therefore, crucial for comprehending how and why intended learning goals are (not) translated into the classroom (e.g., Cobb & Jackson, 2015; Coburn, 2003; Maass et al., 2019; Morris & Hiebert, 2011).

## **INTENDED LEARNING GOALS FOR PROSPECTIVE EC EDUCATORS RELATED TO THE TOPIC OF SET PERCEPTION AND DETERMINATION OF CARDINALITY**

Prior to school entry, children should develop the ability to perceive a set of objects in different ways (e.g., in sub-structures) and to use various strategies for determining its cardinality (e.g., subitizing) (Carmichael et al., 2014; Mulligan & Mitchelmore, 2009; Mulligan et al., 2020; Sprenger & Benz, 2020). Following Schöner and Benz (2018), a set can be perceived either (1) as individual elements, (2) as a whole, or (3) in (sub-)structures. A set's cardinality can be determined by using either (I) counting strategies, (II) derived facts (non-counting), or (III) known facts.

The way a set is perceived is indicative for how its cardinality may be determined, and these two processes can occur either sequentially (first perceiving, then determining) or simultaneously (Schöner & Benz, 2018; Sprenger & Benz, 2020). Perceiving a set and instantly determining its cardinality without any conscious mental process is referred to as (perceptual) subitizing (e.g., Clements & Sarama, 2020; Kaufman et al., 1949). Quasi-subitizing is often discussed in relation to and distinguished from subitizing (e.g., Benz et al., 2015). Other terms for quasi-subitizing in the literature are, for example, conceptual subitizing (e.g., Clements & Sarama, 2020), or structural subitizing (e.g., Schöner & Benz, 2018; Sprenger & Benz, 2020).<sup>3</sup>

Vocational school teachers should provide prospective EC educators with a deep understanding of these mathematical concepts and abilities that children need to learn (e.g., Gasteiger & Benz, 2018; Leavy & Hourigan, 2018). Prospective EC educators should understand that there are multiple ways to perceive a set and to determine its cardinality. They should allow children to use different strategies and encourage them to try out alternative approaches, ask them to explain how they determined the number of objects, and discuss strategies with them (Clements & Sarama, 2020). To prevent the over-emphasis on counting strategies in practice, prospective EC educators should acquire knowledge about the role of non-counting strategies, such as subitizing (e.g., Fuson, 1988). Nonetheless, the development of (quasi-)subitizing in children should be explicitly linked to their counting experiences (Clements & Sarama, 2020). Additionally, EC educators should recognize that multiple factors influence the perception of a set and the determination of its cardinality. For instance, wide spatial distribution of the objects or differences between individual objects (shape, color, size) might hinder (quasi-)subitizing and encourage one-by-one counting (Clements & Sarama, 2020; Splinter et al., 2024).

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<sup>3</sup> These terms vary in their definition and distinction from subitizing across the literature based on, for example, the set size, if the set is perceived in sub-structures (Clements & Sarama, 2020; Schöner & Benz, 2018) or if any conscious mental process is involved (Schöner & Benz, 2018; Sprenger & Benz, 2020).

Taken together, there are two central content learning goals for prospective EC educators regarding their explicit knowledge of set perception and cardinality determination:

Learning goal 1 (LG 1): Prospective EC educators should realize that they themselves may perceive sets in various ways (e.g., in structures) and use different strategies to determine their cardinality (e.g., through subitizing).

Learning goal 2 (LG 2): Prospective EC educators should become familiar with a wide range of strategies for perceiving sets and determining their cardinality, as well as factors (e.g., set size, spatial arrangement) that can influence the application of these strategies.

Below, the learning activity “How many? - Gaining experience in set perception and determination of cardinality” (hereafter referred to as “How many?”) from the EmMa-FS curriculum material is presented. This learning activity is designed to support prospective EC educators to achieve these two learning goals.

### ***The EmMa-FS curriculum material and “How many?” – A learning activity for prospective early childhood educators***

This study focuses the EmMa-FS curriculum material on teaching numeracy in early childhood education, which consists of:

- An introductory text covering the theoretical background (approximately five pages);
- A proposed lesson plan for the initial training of EC educators, comprising three units of 90 minutes each;
- A commented and adaptable PowerPoint presentation aligned with the lesson plan; and
- Various lesson materials aligned with the lesson plan, such as worksheets, videos showcasing typical mathematical learning situations with children in EC settings, and a list of materials for children with potential for early years mathematics education (e.g., games, picture books).

The learning activity “How many?”, which is part of the suggested lesson plan on conceptual understanding of quantities, aims at building prospective EC educators’ explicit knowledge of set perception and cardinality determination (LG 1, LG 2). This learning activity is explicitly not designed as an example of conducting early years mathematics education but to incite EC educators to reflect on intra- and inter-individual differences in perceiving sets and determining their cardinality.

In the beginning of the learning activity, the prospective EC educators are split up into smaller groups of four or five to enable student centered discussions. Each group receives three small bowls, each containing small objects of the same kind (e.g., small coins) in an unknown amount (suggested are five, ten and fifteen objects). The groups position themselves in small circles and one student empties the first bowl so that its content scatters in a random arrangement. Group members are then requested to determine the number of elements as quickly as possible. Ideally, the students should stand rather than sit, as the increased height prevents objects falling on top of each other which could impair set perception. This way the objects may distribute in small clusters, supporting the perception of the set in structures. It is beneficial to use materials that lay flat immediately. If objects tend to roll or bounce easily, they are more likely to scatter widely, hindering the application of non-counting strategies, even for small set sizes. After each round, the group discusses how each member determined the cardinality. For example, they might just have seen (i.e., subitized) the number of objects, counted them or recognized known patterns (e.g., the dice-four). Since students might perceive the same set differently, this reflection allows them to discuss the role of influential factors such as the spatial arrangement and set size.

After three rounds, the vocational school teacher gathers the students’ observations in a classroom discussion, writes down the described strategies (e.g., on a whiteboard), and organizes the observations into different categories (e.g., counting, subitizing, using sub-structures). The teacher may engage the students in categorizing the reported observations by identifying similarities and contrasting differences. Ideally, students are encouraged to participate in this process without using any technical terms, focusing instead on the noted differences. Either simultaneously or afterwards, the teacher discusses with the class whether strategies changed depending on set size or spatial arrangement of the objects.

Within the suggested EmMa-FS lesson plan, this learning activity is followed by a theoretical input from the vocational school teacher to consolidate the newly gained knowledge and to introduce technical terms in reference to the students’ reported observations. The curriculum material includes PowerPoint slides that complement this theoretical input.

In addition to receiving the curriculum material, some participants attended an in-person PD course (one course day per content module, six hours each), where this learning activity was demonstrated.

## **RESEARCH QUESTIONS**

To ensure high quality learning opportunities for students, it is desirable that teachers implement curriculum material in line with its intended learning goals (e.g., Cobb & Jackson, 2015; Coburn, 2003; Maass et al., 2019; Morris & Hiebert, 2011). To prevent misalignments between teachers’ implementation and intended learning goals, potential origins of misalignments should be identified. This way, curriculum material designers can anticipate potential causes for misalignments beforehand and include countermeasures against them in their designs.

Previous research suggests that teachers’ implementation of a suggested learning activity in their lesson designs particularly depends on how they interpret and prioritize the intended learning goals embedded within the curriculum material (e.g., Brown, 2009; Karsenty et al., 2023; Leufer et al., 2019; Schoenfeld, 2010). Thus, teachers’ personal goals seem especially likely to cause misalignments regarding intended learning goals (e.g., Prediger et al., 2022). But further research is needed on the extent to which teachers’ personal goals might interfere and cause misalignments between teachers’ implementation of curriculum material and

its intended learning goals (e.g., Şahin-Gür & Prediger, 2023). As misalignments may arise either during lesson planning or later during enactment, both components of lesson design must be considered simultaneously (e.g., Brown, 2009; Remillard & Heck, 2014). This study aims to advance this area of research by addressing the following research questions:

**RQ 1** How do vocational school teachers implement the learning activity “How many?” on the topic of set perception and determination of cardinality in their lessons for prospective EC educators? To what extent are their implementations aligned with the intended learning goals of the learning activity?

**RQ 2** Which personal learning goals of vocational school teachers are evident in their implementation of the learning activity? To what extent do these personal goals interfere with the intended learning goals of the learning activity “How many?”?

## METHODS

### Sample

To investigate the two exploratory research questions, a qualitative multiple case study was conducted (Creswell, 2014; Yin, 2018). The convenience sample consisted of eight vocational school teachers. Participation in this study was voluntary, and each participant gave their informed consent. Prior to this study, the vocational school teachers had participated in a PD program on the topic of early mathematics education for prospective EC educators as part of a larger research project (see Richter et al., 2025). Five participants (Paul, Pia, Petra, Penny, Patricia) had received an in-person PD course as well as curriculum material. The other three participants (Mona, Mable, Margaret) had received only the curriculum material prior to data collection and were offered an in-person PD workshop after the presented study had concluded.

The sample was relatively heterogenous regarding age, form of initial teacher training, specialized subjects, experience as a vocational school teacher in general and experience in teaching early years mathematics education for prospective EC educators. This heterogeneity enables contrasting the different cases (Yin, 2018). **Table 1** provides a detailed overview of the participating vocational school teachers.

### Data Collection

To gain insight into the lesson planning and enactment of the participating vocational school teachers, teachers, they were asked to record and submit a video of the (first) lesson in which they covered the conceptual understanding of quantities along with a tabular lesson plan and all prepared lesson materials. The goal was to observe vocational school teachers' use of the curriculum material as naturally as possible, focusing on if and how their implementations aligned with the intended learning goals. “How many?” is only a suggested learning activity and it was not necessary for vocational school teachers to implement this activity to design a lesson aligned with LG 1 and LG 2.

To triangulate the data (data triangulation; see e.g., Flick, 2017), each vocational school teacher was interviewed after recording and submitting the lesson videos. The semi-structured interviews were divided into three parts. The first part addressed the vocational school teachers' general process of planning the recorded lesson. The second part focused on their use of the EmMa-FS curriculum material in this process, including their reasons for adapting or omitting specific elements of the suggested lesson plan on conceptual understanding of quantities (e.g., the learning activity “How many?”). The third part allowed the vocational school teachers to reflect on their recorded lesson, discussing their satisfaction with the lesson design, any potential changes, additional support needs beyond the EmMa-FS curriculum material, and whether the study's context (e.g., recording the lesson) influenced their lesson design.

Data collection was conducted between September 2022 and March 2023. The lesson recordings were scheduled to align with participants' pre-existing semester plans and individual school curricula. Technical equipment was provided. Immediately after the recordings, participants submitted the equipment, recorded lessons, prepared lesson plans, and all used materials (e.g., worksheets, presentation slides). As soon as they were available, the first author reviewed the recorded lessons to prepare for the interviews. All interviews were conducted by the first author within a maximum of two weeks after the respective lesson was recorded. The length of the recorded lesson videos and interviews is reported in **Table 1**.

### Data Analysis

The data analysis was conducted in collaboration by the two authors through an iterative process. First, sections of the lesson plans and videos, in which set perception and determination of cardinality were covered, were identified. Next, to determine if and how participants had implemented “How many?”, the lesson plans and recorded videos were descriptively analyzed using qualitative content analysis (Mayring, 2015). Following Brown (2009), the following deductive codes were employed: (1) offloading, (2) adapting, and (3) improvising. For the lesson videos, the coding process adhered to Brown's (2009) original characterization of these terms by using them as a continuous scale to describe whether the instructional agency rested more with the curriculum material or the participating vocational school teacher (see Brown, 2009). For the lesson plans, the same three codes were applied as follows:

- The code (1) offloading was used if the participants had followed the suggested lesson plan (almost) verbatim,
- The code (2) adapting was used if they had made significant changes (e.g., changes in the overarching structure or the basic principle of emptying a container), and
- The code (3) improvising was used, if they had omitted the learning activity “How many?” entirely.

**Table 1.** Detailed overview of participants and collected data material

Pseudonym	Petra	Pia	Mona	Patricia	Paul	Margaret	Penny	Mable
Age (in years)	52	63	36	52	49	56	46	49
Initially trained for school level	Secondary school	Secondary school	Vocational school	Vocational school	Secondary school	Vocational school	Vocational school	No formal teacher training
Initially studied mathematics	No	Yes	Yes	No	Yes	No	No	No
Experience as vocational school teacher (in years)	5	37	7	6	16	30	13	3
Teaching secondary school level mathematics	No	Yes	Yes	No	Yes	No	No	No
Participation in PD programs on early years mathematics education prior to EmMa-FS	No	Yes	No	Yes	Yes	Yes	No	No
Experience in teaching early years mathematics education prior to EmMa-FS (in lesson units of 45 minutes)	0	~ 2000	25	40	~ 500	16	0	0
Experience with the EmMa-FS curriculum material for "Numbers" (in lesson units of 45 minutes)	6	2	0	0	0	0	0	2
Length of lesson recording (in minutes)	65	128	45	67	225	140	23	78
Length of interview recording (in minutes)	27	68	48	39	72	39	67	41

After the descriptive data analysis, it was assessed to what extent the participants' lesson designs were suited for achieving LG 1 and 2. To later explore the origins of any misalignments, we evaluated each participant's lesson planning (submitted lesson plans and materials) and enactment (recorded videos) separately. Aspects of each participant's planning and enactment of the learning activity "How many?" that were either appropriate or (potentially) inappropriate regarding the intended learning goals (e.g., choice of material, instructional prompts, teacher moves during classroom discussions) were identified. If participants had omitted the learning activity, we instead analyzed the previously identified sections that covered set perception and determination of cardinality and evaluated whether they were aligned with LG 1 and 2. If set perception and determination of cardinality was not covered at all, the participant's lesson design was automatically considered to not be aligned with LG 1 and 2.

To reconstruct the participants' personal goals, the participants' planning and enactment of the learning activity learning activity were examined for indications that they had adopted the intended learning goals as their personal goals. Simultaneously, it was sought after evidence of personal goals that participants might have pursued instead. Next, the findings were triangulated with the interview data, identifying sequences where participants explicitly (e.g., by stating concrete goals) or implicitly (e.g., by discussing their overarching lesson design principles) reasoned about their personal goals. Finally, the accumulated findings were used to re-construct each participant's personal goals.

Throughout this process, regular meetings with other researchers were held to discuss the results and to ensure objectivity and validity of the coding and data interpretation (data interpretation in groups; see also Maier, 2018).

## RESULTS

In the following, each of the eight cases is presented, starting with the cases of Petra, Pia, Mona and Patricia, who all had implemented "How many?". Petra's case will be discussed in detail to illustrate the data analysis and interpretation process. For each case, the extent to which the respective participant's implementation was aligned with the intended learning goals of "How many?" (RQ1) will be discussed as well as if their personal goals were potentially interfering with the intended ones (RQ 2). Afterwards, results for Paul, Margaret, Penny, and Mable, who all omitted the learning activity "How many?", are briefly summarized.

### Implementing the learning activity "How many?": Petra, Pia, Mona and Patricia

#### *Petra - Adopting intended learning goals as personal goals*

##### **Lesson planning**

Petra planned to prepare three small, shallow containers for each group, filling them with five, ten and fifteen reversible tiles<sup>4</sup>, respectively. Petra scheduled "How many?" at the beginning of the lesson on conceptual understanding of quantities, followed by a theoretical input as suggested in the EmMa-FS curriculum material. This setup enables students to first realize that there are multiple possibilities to perceive a set and determine its cardinality (LG 1) before discussing the range of strategies and influencing factors (LG 2) (see Section *Intended Learning Goals*). Petra's planning of the learning activity "How many?" is thus well-aligned with the intended learning goals but also followed the curriculum material very closely which indicated that she offloaded her lesson planning on the suggested lesson plan entirely.

<sup>4</sup> Reversible tiles (German: „Wendepfättchen“) are small round tiles with different coloration on each side – typically red and blue, but other color combinations are possible. They are commonly used in primary mathematics education in Germany.

### Lesson enactment

In the videotaped lesson, Petra paraphrased the instructions suggested in the curriculum material and reiterated key prompts as needed (e.g., urging her students to stand up instead of sitting down during the activity). Through emphasis, Petra directed her students' attention to variations in their strategies for determining cardinality (LG 1). Additionally, she instructed the small groups to document their findings after each round before proceeding. This approach encouraged students to closely observe their perceptions of the sets and methods for determining cardinality. This focus on differences between the students' observations later facilitated Petra's discussion on the nuances between strategies and influencing factors regarding set perception and determination of cardinality (LG 2).

Petra initiated the classroom discussion by asking her students to give a detailed description of how they determined that there were five tiles in the first container. She repeatedly prompted her students to focus their reports on the process of how exactly they perceived the sets and determined the number of objects rather than the result of this process (LG 1) and highlighted differences between the described strategies (LG 2). Petra's approach thus aligns with both intended learning goals as she especially ensured in-depth reflection on the students' strategies by focusing on details such as the influence of coloration or spatial arrangement of the reversible tiles. She repeatedly demonstrated this attention to detail by asking students to elaborate on their observations (e.g., "How did you recognize there were four and one [tiles]?"). Petra further supported the discussion by listing the students' reports as bullet points on the blackboard. While she did not immediately categorize the reports as it is suggested in the curriculum material. Petra later directly referred to individual bullet points and correctly matched them to the different strategies included in the theoretical input. Overall, Petra's enactment of the learning activity "How many?" fully aligned with the intended learning goals. This also indicated that she primarily offloaded her enactment of the learning activity on the EmMa-FS curriculum material.

### Personal learning goals

Multiple instances throughout Petra's lesson design and enactment indicate that she adopted the intended learning goals of "How many?" as her personal goals. Her selection of the materials matched with the materials used in the PD course which she attended. Petra's active discussion of coloration in connection to the part-whole relationship in the videotaped lesson suggests that this choice was intentional and based on a deeper understanding of the materials recommended for this activity. Petra's instruction indicated that she also understood the benefit of having students stand in a circle rather than sit. Lastly, Petra's detailed and targeted questions within the classroom discussion suggest that she aimed for the students to recognize differences in their reported observations and strategies (LG 1) and to pay particular attention towards the origin of these differences (LG 2). Because Petra was able to adequately reference the student reports she had written down on the blackboard throughout the theoretical input, it can be assumed that she aimed for the students to gain knowledge and a solid understanding of the different strategies to determine cardinality (LG 2).

When asked directly about the learnings goals of the lesson in the interview, Petra stated that she did not explicitly write them down and therefore, her (explicit) goals for the lesson were not discussed further. Nonetheless, several indications in the interview also support our assumption that Petra's personal goals were congruent with the intended learning goals. For example, when asked why she included the learning activity in her lesson, Petra recounted her experiences from the PD course and emphasized the personal enrichment of discussing and comparing her perception of the same set and strategies to determine its cardinality with other PD participants. She wanted her students to have similar experiences. For this reason, Petra highlighted in the classroom discussion that multiple strategies may achieve the same result (LG 1). Petra also stated she was satisfied with the classroom discussion as it brought forth a wide range of strategies (LG 2). She felt the activity supported the students' understanding of the following theoretical input because they could gather first-hand experiences with different strategies such as (quasi-)subitizing. It can be concluded that Petra aimed for her students to become aware of the existence of different strategies (LG 1). She also recognized the importance of personal experience in constructing sustainable theoretical knowledge on different strategies and influencing factors to determine cardinality (LG 2).

### *Pia - Implementation in line with intended learning goals without adopting them as personal goals*

#### Lesson planning

Pia planned to use small stones in different sizes as her material for the activity "How many?". In general, small stones are a suitable choice of material for this learning activity, as long as the size variation is minimal and does not interfere with, for example, perceiving the set as a whole (see Section *Intended Learning Goals*). To structure students' results in the subsequent discussion, Pia prepared an additional three-fold scheme similar to the suggested one. Overall, Pia's planning of the learning activity "How many?" was aligned with the intended learning goals as she mainly offloaded the lesson planning onto the suggested lesson plan, supplementing it with some written notes.

#### Lesson enactment

Unlike Petra, who paraphrased the instructions within the curriculum material, Pia repeated them verbatim by reading them aloud from her personal notes. Pia's initial questions in the classroom discussion were suitable to the intended aim of the activity. Nonetheless, a considerable amount of the differences the students identified remained at a surface level. For example, one group reported that some group members counted aloud and others silently as a difference in their strategies. Regardless, Pia accepted all reports equally by writing them down on the blackboard. She changed her original plan to immediately sort the reports according to her prepared scheme –thereby adapting the EmMa-FS curriculum material as well – and wrote them down in chronological order instead. Taken together, Pia at first offloaded the instruction part on the curriculum material. In the discussion part she then slightly adapted it by deviating from the threefold scheme and simply writing down all student reports.

### Personal learning goals

In summary, while Pia's enactment was mostly aligned with LG 1 and 2, minor limitations arose during her moderation of the classroom discussion, as she did not address the irrelevant student reports. Thus, her lesson planning and enactment indicate that Pia's personal goals at least overlapped with the intended learning goals. Her moderation of the discussion, however, may hint that her personal goals were not identical to the intended learning goals of the activity "How many?".

The interview revealed that Pia struggled to spontaneously handle and categorize the students' reports according to her prepared scheme specifically due to her uncertainties regarding the content. She displayed difficulties articulating the differences between strategies for determining cardinality and repeatedly expressed feelings of inadequacy regarding her professional knowledge. Although Pia's responses regarding her goals for the recorded lesson indicated a general understanding of the intended learning goals, her rather heavy reliance on the curriculum material, as seen in both the recorded lesson and the interview, suggests that she may not have fully adopted the intended learning goals as her personal goals. Instead, it appears she did not set any other concrete personal goals. The misalignments between Pia's moderation of the classroom discussion and the intended learning goals may therefore be attributed to a lack of clear goal-focus.

### *Mona – The same activity but different learning goals*

#### Lesson planning

Unlike Petra and Pia, Mona selected different materials for each of the groups. One of the groups received marbles, which are an unsuitable choice of material for this specific learning activity because they roll away easily (see Section *Intended Learning Goals*). The other chosen materials were appropriate. Overall, Mona's planning of the learning activity "How many?" was mainly aligned with the intended learning goals as she still mostly offloaded her lesson planning on the curriculum material.

#### Lesson enactment

In her enactment, Mona slightly adapted the instruction from the EmMa-FS curriculum material. Compared to Petra and Pia, her instruction displayed some limitations concerning the intended learning goals: While she included most of the relevant prompts from the suggested lesson plan, Mona did not encourage her students to carefully observe their own perceptions and strategies. Instead, she framed the learning activity as an opportunity for the students to adopt the perspective of a child. This prompt could interfere with LG 1 by shifting the students' focus away from analyzing their own strategies to determine cardinality. By stating that students may no longer be able to "subitize" in the second round, Mona used a technical term in her instruction that students were likely unfamiliar with at this point. It could also imply she expected all students to subitize in the first round. This restrictive assumption conflicts with both LG 1 and LG 2. During the classroom discussion, Mona repeatedly used technical terms to label the students' reports and asked leading questions (e.g., "How did you do it? Probably just like with the second set?"). She appeared to focus on introducing (all) different strategies and their technical terms to prepare for the theoretical input. In sum, Mona's enactment of "How many?" displayed significant limitations regarding the intended learning goals.

#### Personal learning goals

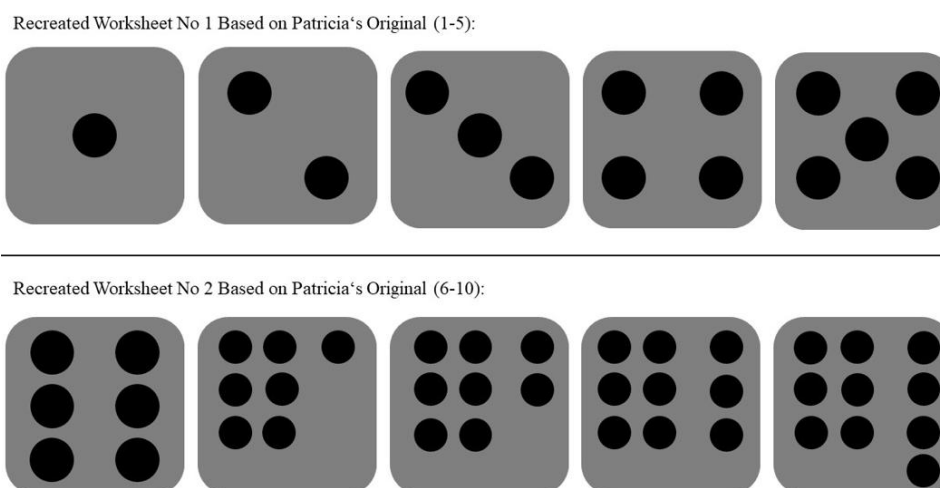
There were multiple indications that Mona did not adopt the intended learning goals of "How many?". This appears to be the main cause of the misalignments described. Instead, it seems Mona's personal goal was to introduce technical terms related to set perception and determination of cardinality while highlighting the theoretical content's relevance for EC education practice.

In the interview, Mona explained she wanted her students to "at least know the basics" on conceptual understanding of quantities. She repeatedly mentioned various theoretical concepts but did not elaborate how they related to her planning and enactment of "How many?". Mona stated that in her understanding of the learning activity the students should put themselves in a child's position. She continued by describing how well it worked out, explicitly mentioning that all students were able to subitize in the first round. She also felt satisfied with how the theory was integrated practically. Taken together, while Mona's implementation of the learning activity "How many?" did not fully align with the intended learning goals, it was well aligned with her personal goals.

### *Patricia – A different activity and diffuse learning goals*

#### Lesson planning

Patricia planned not to use containers filled with materials, but she utilized a four-page worksheet she found online. Each page displayed five figures with structured sets of one to twenty dots, ordered by set size. A recreation of the worksheet is depicted in **Figure 1**.



**Figure 1.** Recreation of Patricia's worksheets (Source: Authors' own elaboration)

The worksheet that Patricia selected caused serious limitations regarding the intended learning goals: Since the sets are ordered and highly structured the same strategy to determine cardinality could be applied to each set. Thus, in Patricia's adaptation of "How many?" students are unlikely to realize that there are different strategies for determining cardinality (conflicting with LG 1). According to the notes in her lesson plan, Patricia assumed that all students would subitize in the first round. Any differences of how the sets are perceived and how their cardinality is determined are likely attributed solely to set size (a limitation to LG 2). In Patricia's setup, all students work with the same figures, eliminating any variation in set characteristics between the small groups and, thus, limiting variation in strategies to determine cardinality. Additionally, having five sets visible at once in the first two rounds and ten in the third hinders the students to focus on one set at a time. Although clearly inspired by "How many?", Patricia heavily adapted the EmMa-FS curriculum material, and her planning already displayed significant limitations regarding the intended learning goals.

#### **Lesson enactment**

Following her lesson plan, Patricia alternated between instruction and classroom discussion for each of the three rounds. This required her to adapt the instruction suggested in the curriculum material. Patricia split up her class in pairs of two and placed the worksheets face down before each pair. For each round, she then requested the students to turn over the respective worksheet and to quickly determine the number of dots in all figures. Patricia did not prompt the students to pay close attention to their own strategies when determining the sets' cardinality. Additionally, she did not ask the students to discuss their strategies with each other but to merely write down the determined cardinality beside each figure. In relation to the curriculum material, her enactment of the activity bordered on improvising.

Within the discussion, Patricia focused mainly on how the cardinality of highly structured sets could be determined with a single look (i.e., subitized), while unstructured sets required one-by-one counting. Although Patricia recognized the role of spatial arrangement in determining cardinality, her explanation was overly simplistic. By suggesting that structured sets are (always) subitized and unstructured sets are (always) counted, Patricia may have led students to incorrectly believe that these are the only two strategies for determining cardinality. Like Mona, Patricia did not document the students' reported strategies and observations.

#### **Personal learning goals**

Overall, Patricia's enactment of the learning activity "How many?" did not align with the intended learning goals. It appears she instead aimed to demonstrate that small or highly structured sets can be subitized, whereas bigger or unstructured sets must be counted individually.

Throughout the interview, however, it appeared that Patricia's personal goals were not entirely different from the intended ones. Regarding her personal goals, she stated that she aimed for the students to understand how set perception and subitizing work. In addition, she wanted to provide first-hand experiences and enable the students to correctly use technical terms. Initially, this response aligns with LG 1 and 2 – to know a wide range of strategies for determining cardinality and connect the theoretical input to the experiences gathered in the learning activity. However, Patricia's emphasis on subitizing and spatial arrangement as well as her oversimplified treatment of the theory conflicted with the intended learning goals. In sum, it seems she did not establish distinct personal goals but rather misunderstood or misinterpreted the intended learning goals.

#### **Omitting the Learning Activity "How Many?": Paul, Margaret, Penny and Mable**

While Paul and Margaret omitted the learning activity "How many?", both covered the content of set perception and determination of cardinality. We briefly summarize to what extent their lesson designs aligned with LG 1 and 2 and which personal goals may have interfered.

Penny and Mable did not include any content on set perception and determination of cardinality. Hence, their lessons did not align with the intended learning goals of "How many?" and the interviews centered more on their reasons for focusing on the instead covered content rather than omitting "How many?" specifically. Nonetheless, we will roughly outline the content focus of their lesson designs.

### ***Paul – Avoiding concrete goals and plans***

Paul gave a theoretical input, in which he explained (quasi-)subitizing in detail using example figures from the EmMa-FS curriculum material and discussing the influence of spatial arrangement and set size on the determination of cardinality (LG 2). Paul's lesson further covered university-level set theory and the development of counting abilities. Paul's lesson design therefore only partially aligned with the intended learning goals of "How many?"

In the interview, Paul expressed strong resentment towards his inclusion of set theory, feeling it was irrelevant for his students. He preferred to limit theoretical input to content with clear practical applications, such as subitizing. In the context of the study, Paul felt pressured to adopt a more theoretical approach. When asked about his personal goals, he said he disliked setting goals for individual lesson units and preferred more general goals (e.g., for the entire school year). Paul's personal goal at that time was to reduce math anxiety among his students and provide them with concrete, practical examples. Presumably, he omitted "How many?" because he disliked following rigid plans and preferred to act spontaneously. Consequently, he did not review the suggested lesson plan in his preparations.

### ***Margaret – Severe time restrictions lead to content restrictions***

Margaret had only seven lesson units (315 minutes) on a single day to cover the entire field of early years mathematics education. Consequently, she had to omit most content and learning activities from the EmMa-FS curriculum material (30 lesson units = 1,350 minutes). She included only a brief theoretical input on set perception and determination of cardinality, focusing on (quasi-)subitizing. She did not discuss influencing factors such as spatial arrangement. Therefore, Margaret's lesson was only partially aligned with LG 2 but not LG 1.

In the interview, Margaret stated that her goal for the lesson was to maximize time for practical activities by minimizing theoretical input. Regarding the omission of "How many?", she felt it would take too much time that she preferred to allocate to other learning activities. Margaret hoped that the remaining activities would compensate for this omission, but she could not provide a concrete rationale for her belief. She later reflected that including "How many?" would have been beneficial to engage or motivate her students.

### ***Penny – Omitting conceptual understanding of quantities in favor of counting abilities***

Penny's lesson design primarily focused on the development of counting abilities, supplemented by input on proto-quantitative schemes. In her interview, she outlined two personal goals for her lesson: First, Penny wanted her students to acquire solid theoretical knowledge; second, she aimed to avoid overloading them with technical terms or content she considered irrelevant. A tension existed between the competences she believed her students would need for their future work and the low expectations she placed on them within her lessons. It is possible that Penny omitted any input on set perception and determination of cardinality because she did not perceive it as important for her students.

### ***Mable – Approaching early years mathematics education from the perspective of developmental psychology***

Since she taught in the same federal state as Margaret, Mable also had to work with a severely limited amount of lesson time. This restriction caused her to omit all content on the conceptual understanding of quantities. Mable instead focused on number aspects in her recorded lesson. In the interview, she explained that her personal goal was mainly rooted in her background in developmental psychology and play pedagogy. Mable aimed to provide her students with enjoyable and accessible learning opportunities to reduce their math anxiety. When recounting the lesson, she focused more on overarching principles of early years education and developmental psychology in general instead of early years mathematics education specifically. It is possible that Mable omitted all content on the conceptual understanding of quantities because she did not see its connection to developmental psychology and play pedagogy.

## **LIMITATIONS**

Before discussing the results of our study, some of the most central limitations to the study's research's design and scope have to be pointed out. The open-ended assignment for the participants to record the respective lessons in which they covered the conceptual understanding of quantity caused two challenges: First, because the implementation was not mandatory, four participants omitted "How many?". The participants' decisions were not necessarily due to content-related reasons but often based on personal preferences and sometimes because they did not review all curriculum material provided. Although this is an interesting observation, this study's scope did not permit to further examine their reasoning. Only four participants implemented the learning activity and their implementations' alignment with the intended learning goals varied greatly. While analyzing and comparing distinct cases is valuable to gain deeper insight into teachers' use of curriculum material, the study's small and diverse sample does not capture all possible variations and does not allow to generalize the results.

Next, the amount of available data varied between the participants. In some cases, this was due to some technical difficulties with the lesson recordings. For example, Mona and Patricia recorded their first lessons without sound because the external microphones were not properly connected to the video recorder. Mona luckily was able to repeat the recording with another one of her classes. Patricia, however, had no such opportunity. Because of this there was only a lesson recording of 20 minutes available to analyze in Patricia's case. However, these 20 minutes showed Patricia's enactment of the learning activity "How many?". While some technical difficulties would have been avoided if we had recorded the lessons ourselves, we wanted the

teachers (and the students) to act as naturally as possible given the circumstances. We deemed that our presence would impede this more than if the teachers recorded themselves.

## DISCUSSION

Fidelity of implementation is a key factor for successfully delivering educational innovation through curriculum material (Century & Cassata, 2016). Thus, it is important to understand how and why or why not teachers implement curriculum material appropriate to its desired outcomes when they design their lessons (e.g., Century & Cassata, 2016; Cobb & Jackson, 2015; Coburn, 2003; Maass et al., 2019; Morris & Hiebert, 2011). The aim of this study was to investigate potential origins of (mis)alignments between teachers' classroom implementation and the intended learning goals of curriculum material.

The first research question aimed to explore how vocational school teachers implemented the learning activity "How many?" and to evaluate whether their implementations aligned with its intended learning goals. It was found that four out of eight vocational school teachers implemented the learning activity in various forms. Notably, only Petra's implementation of "How many?" was fully aligned with the intended learning goals. Pia's, Mona's and Patricia's implementations exhibited (either major or minor) limitations concerning the intended learning goals. These misalignments emerged at different stages of their design process: In the planning of the learning activity (Patricia), in the enacted instruction (Mona) or in the enacted classroom discussion (Pia). The lesson designs of the other four vocational school teachers (in which "How many?" was omitted) either partially (Paul and Margaret) or not at all (Penny and Mable) aligned with the intended learning goals.

Taken together, the results on RQ 1 support previous research results that designing a lesson based on curriculum material is a challenging task in general (e.g., Cevikbas et al., 2024). The results suggest that even changes to small details of the setup (e.g., choice of material), instruction (e.g., explicit focus on differences in strategies for determining cardinality), and classroom discussion (e.g., response to irrelevant student contributions) significantly impacted the alignment of the activity "How many?" with its intended learning goals. Moreover, it was especially challenging for the participants to moderate the classroom discussion in alignment with the intended learning goals. While effectively moderating the classroom discussion is crucial for achieving the intended learning goals of "How many?" (see also, e.g., Herbel-Eisenmann & Otten, 2011; Wood et al., 2001), this task requires extensive experience and a clear goal-focus (see also, Karsenty et al., 2023; Prediger et al., 2022).

According to Brown (2009), teachers need a high degree of PDC to design lessons in line with their personal goals. However, teachers' personal goals may not necessarily align with the intended goals of curriculum material. Previous research has shown that teachers' perceptions, interpretation, and consequently their use of curriculum material are influenced by their personal goals (Brown, 2009; Prediger et al., 2022; Remillard & Heck, 2014). The second research question aimed to uncover participants' personal goals and the extent to which they influenced the identified (mis)alignments with the intended learning goals.

Considering Brown's (2009) DCE framework, it seems likely that Petra, Mona and Penny possess a rather high degree of PDC. All three were able to design lessons in line with their respective personal goals. Nonetheless, the results revealed that only Petra's implementation of "How many?" aligned with its intended learning goals as she alone had adopted them as her personal goals. Petra indicated in the interview that this was the second time she implemented the learning activity "How many?" and that her lesson design relied on her previous experiences. Familiarity with curriculum material in general seems to be beneficial to the alignment of teachers' lesson design with intended learning goals (e.g., Brown, 2009).

Mona and Penny pursued personal goals that differed from the intended ones. Mona, therefore, re-contextualized "How many?" as an opportunity for students to take up children's perspective. This led to a misalignment regarding the learning activity's intended learning goals. Together with Mona's focus on technical terms, this may have hindered students from intentionally reflecting various influences on set perception and determination of cardinality. However, intentional reflection is crucial for developing prospective EC educators' knowledge and understanding of central mathematical concepts (e.g., Leavy & Hourigan, 2018). Penny omitted the content set perception and determination of cardinality entirely. Instead, she put heavy emphasis on the development of counting abilities. While her lesson design might have been suited for her personal goals, an overemphasis on counting abilities disregards of other important mathematical competences children should develop such as subitizing (e.g., Clements & Sarama, 2020).

Pia, Patricia, and Paul had diffused goals, possibly indicating a lower degree of PDC on their side. However, in Pia's case, this only interfered with the intended learning goals during her classroom discussion. Here, she was unable to appropriately deal with unexpected student contributions. This was potentially caused by Pia's insecurities regarding the content. This might also indicate insufficient content knowledge on her side – a prerequisite for designing high quality lessons (e.g., Brown, 2009; Kulgemeyer & Riese, 2018). In comparison, Patricia did not consider if the worksheets she used were an appropriate modification of "How many?". If she had had more concrete goals Patricia might have chosen figures displaying a wider variation of spatial arrangement. This hints that Patricia possesses less PDC than Pia. Paul had misunderstood the EmMa-FS curriculum material because he had not worked through it completely due to his aversion to detailed lesson planning. In his case, it may be that not a low degree of PDC caused misalignments but his seemingly negative attitude towards curriculum material in general (e.g., Remillard & Heck, 2014).

Lastly, Margaret and Mable both had to deal with serious time constraints. Additionally, their personal goals focused primarily on reducing math anxiety by minimizing theoretical input. As a result, they did not recognize the content of set perception and determination of cardinality to be of importance for their students and instead prioritized other and sometimes less important content from the EmMa-FS curriculum material. It is a common problem that teachers have significant less lesson units available to teach a specific content area, than what could be considered ideal (e.g., Leufer et al., 2019). Nonetheless, it is possible that

teachers with a higher degree of PDC would be able to balance severe constraints while maintaining alignment with intended learning goals.

Summing up the results on RQ 2, multiple factors which may constrain the alignment of teachers' lesson design with curriculum material's intended learning goals were found. First, teachers' attitudes towards curriculum material or their willingness to invest more than a minimal amount of effort to prepare their lessons (Paul and Patricia). Second, insufficient content knowledge or an incomplete or oversimplified understanding of the content (Patricia, Margaret, Mable, and, to an extent, Pia). Third, prioritization of general pedagogical or atmospheric goals (e.g., reducing math anxiety) by minimizing theoretical input (Margaret, Mable, and Paul, who expressed a strong aversion towards the amount of theory he included in his lesson design). Fourth and last, severe time constrictions were a major issue (as seen in Mable's and Margaret's cases). Together, these cases show how teachers may struggle with selecting and prioritizing intended learning goals effectively because their decisions which content or learning activities to include or omit were seemingly based on individual preferences instead of the intended learning goals (e.g., Remillard & Heck, 2014). While math anxiety is a common issue among EC educators in Germany (Jenßen, 2022), avoiding theoretical input is no sustainable solution to this problem as it is a central part of EC educators' math-related competence (Gasteiger & Benz, 2018). The importance of teaching theory applies to other contexts as well. Thus, the prioritization of general pedagogical or atmospheric goals over content-specific learning goals might be the most severe constraint regarding the alignment of teachers' lesson design with intended learning goals.

Regarding affordances, it seemed to be most important that teachers adopt intended learning goals as their personal goals. Also, teaching experience (Pia especially), content knowledge (Pia and Mona), familiarity with the curriculum material (Petra) and higher degrees of PDC (Petra and Mona) were identified as potential factors that support teachers' ability to design lessons in alignment with intended learning goals. However, Penny's case showcased that even if teachers possess high degrees of PDC, there is no guarantee that they implement curriculum material in line with the intended learning goals. Thus, if teachers do not adopt intended learning goals as their personal goals, students may not be able to reach desired outcomes. The presented study cannot provide best practice examples of how teachers can be supported in adopting intended learning goals as their own. However, misunderstanding the intended learning goals appeared to be a major problem. More explicit explanations of how and why the intended learning goals should be reached could have helped in Paul's or Patricia's cases for example. Additionally, for teachers who have to deal with time constraints, such as Margaret and Mable, it could have helped if they were provided with concrete guidelines on which content to prioritize and how to adapt the curriculum material accordingly (see also Brown, 2009).

## CONCLUSION

The presented study highlights the complexity of implementing curriculum material into classroom practice and underscores PDC as a decisive factor for achieving intended learning goals. This study contributes to the research field of implementing curriculum material in two ways. First, it was a key finding that misalignments with the intended learning goals of the learning activity "How many?" were not apparent in the lesson plans alone. The method of analyzing teachers' lesson designs in two separate steps (planning and enactment) enabled us to gain a more detailed picture of how the lesson designs aligned with the intended learning goals of "How many?". Second, both affordances and constraints were found regarding the alignment with intended learning goals. Taken together, misalignments can originate from small design decisions, limited content knowledge, diffuse or competing personal goals, time constraints, or attitudes toward curriculum material. Notably, alignment was most likely when teachers adopted the curriculum material's intended learning goals as their own and had prior experience with the material. Conversely, prioritizing general pedagogical aims—such as reducing subject-related anxiety—over content-specific goals emerged as a particularly powerful source of divergence. This study thereby underscores the importance of teachers not only unpacking intended learning goals in curriculum material but also adopting them as their personal goals (Borko, 2004; Cobb & Jackson, 2015; Coburn, 2003; Maaß & Artigue, 2013; Prediger & Selter, 2024; Remillard & Heck, 2014).

Overall, the results suggest that successful curriculum enactment requires more than high design competence alone; it depends on the interplay of goal alignment, content understanding, instructional experience, and situational conditions. Supporting teachers in interpreting curriculum material, strengthening their content knowledge, and fostering goal clarity may therefore be crucial for reducing implementation gaps. Future research should further investigate how these factors interact over time and how professional development can systematically promote alignment between intended and enacted curricula.

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**AI statement:** The authors stated that no form of generative AI or AI-based tools were used in this research.

**Declaration of interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## REFERENCES

- Ahl, L. M., Helenius, O., Aguilar, M. S., Jankvist, U. T., Misfeldt, M., & Prytz, J. (2023). Implementation research in mathematics education: A systematic mapping review. *Implementation and Replication Studies in Mathematics Education*, 3(2), 135-199. <https://doi.org/10.1163/26670127-bja10015>
- Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, 25(9). <https://doi.org/10.3102/0013189X025009006>
- Benz, C., Peter-Koop, A., & Grüßing, M. (2015). *Frühe mathematische Bildung. Mathematiklernen der Drei- bis Achtjährigen* [Early mathematical education. Learning mathematics for three-to eight-year-olds]. Springer. <https://doi.org/10.1007/978-3-8274-2633-8>
- Blömeke, S., Dunekacke, S., & Jenßen, L. (2017). Cognitive, educational and psychological determinants of prospective preschool teachers' beliefs. *European Early Childhood Education Research Journal*, 25(6), 885-903. <https://doi.org/10.1080/1350293X.2017.1380885>
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15. <https://doi.org/10.3102/0013189X033008003>
- Brown, M. W. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. T. Remillard, B. A. Herbel-Eisenmann, & G. M. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17-36). Routledge.
- Carmichael, C., MacDonald, A., & McFarland-Piazza, L. (2014). Predictors of numeracy performance in national testing programs: Insights from the longitudinal study of Australian children. *British Educational Research Journal*, 40(4), 637-659. <https://doi.org/10.1002/berj.3104>
- Century, J., & Cassata, A. (2016). Implementation research: Finding common ground on what, how, why, where, and who. *Review of Research in Education*, 40(1), 169-215. <https://doi.org/10.3102/0091732X16665332>
- Cevikbas, M., König, J., & Rothland, M. (2024). Empirical research on teacher competence in mathematics lesson planning: Recent developments. *ZDM – Mathematics Education*, 56(1), 101-113. <https://doi.org/10.1007/s11858-023-01487-2>
- Clements, D. H., & Sarama, J. (2020). *Learning and teaching early math. The learning trajectories approach* (3rd ed.). Routledge. <https://doi.org/10.4324/9781003083528>
- Cobb, P., & Jackson, K. (2015). Supporting teachers' use of research-based instructional sequences. *ZDM – Mathematics Education*, 47(6), 1027-1038. <https://doi.org/10.1007/S11858-015-0692-5>
- Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher*, 32(6), 3-12. <https://doi.org/10.3102/0013189X032006003>
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches* (3rd ed.). Sage.
- Davis, E. A., Palincsar, A. S., Smith, P. S., Arias, A. M., & Kademian, S. M. (2017). Educative curriculum materials: Uptake, impact, and implications for research and design. *Educational Researcher*, 46(6), 293-304. <https://doi.org/10.3102/0013189X17727502>
- Dunekacke, S., & Barenthien, M. (2023). What about early childhood mathematics education in early childhood teacher education? *Zeitschrift Für Pädagogik*, 69(1), 88-110. <https://doi.org/10.3262/ZP2301088>
- Flick, U. (2017). Triangulation in der qualitativen Forschung in der Psychologie [Triangulation in qualitative research in psychology]. In G. Mey, & K. Mruck (Eds.), *Handbuch qualitative Forschung in der Psychologie* [Handbook of qualitative research in psychology] (pp. 278-289). Springer. [https://doi.org/10.1007/978-3-658-18387-5\\_23-1](https://doi.org/10.1007/978-3-658-18387-5_23-1)
- Fuson, K. C. (1988). *Children's counting and concepts of number*. Springer. <https://doi.org/10.1007/978-1-4612-3754-9>
- Gasteiger, H., & Benz, C. (2018). Enhancing and analyzing kindergarten teachers' professional knowledge for early mathematics education. *The Journal of Mathematical Behavior*, 51, 109-117. <https://doi.org/10.1016/j.jmathb.2018.01.002>
- Gueudet, G., & Trouche, L. (2009). Towards new documentation systems for mathematics teachers? *Educational Studies in Mathematics*, 71(3), 199-218. <https://doi.org/10.1007/s10649-008-9159-8>
- Herbel-Eisenmann, B. A., & Otten, S. (2011). Mapping mathematics in classroom discourse. *Journal for Research in Mathematics Education*, 42(5), 451-485. <https://doi.org/10.5951/jresmetheduc.42.5.0451>
- Jenßen, L. (2022). A math-avoidant profession? Review of the current research about early childhood teachers' mathematics anxiety and empirical evidence. In S. Dunekacke, A. Jegodtka, T. Koinzer, K. Eilerts, & L. Jenßen (Eds.), *Early Childhood Teachers' Professional Competence in Mathematics* (pp. 79-98). Routledge. <https://doi.org/10.4324/9781003172529-5>
- Karsenty, R., Pöhler, B., Schwartz, G., Prediger, S., & Arcavi, A. (2023). Processes of decision-making by mathematics PD facilitators: The role of resources, orientations, goals, and identities. *Journal of Mathematics Teacher Education*, 26(1), 27-51. <https://doi.org/10.1007/s10857-021-09518-z>
- Kaufman, E., Lord, M., Reese, T., & Volkman, J. (1949). The discrimination of visual number. *The American Journal of Psychology*, 62(4), 498-525. <https://doi.org/10.2307/1418556>

- Kleeberger, F., & Stadler, K. (2011). *Zehn Fragen - zehn Antworten. Die Ausbildung von Erzieherinnen und Erziehern aus der Sicht der Lehrkräfte. Ergebnisse einer bundesweiten Befragung von Lehrkräften an Fachschulen für Sozialpädagogik. Eine Studie der Weiterbildungsinitiative Frühpädagogische Fachkräfte (WiFF)* [Ten questions – ten answers: The training of early childhood educators from the perspective of teachers: Results of a nationwide survey of teachers at vocational schools for social pedagogy]. WiFF Studien. <https://doi.org/10.25656/01:28592>
- Kulgemeyer, C., & Riese, J. (2018). From professional knowledge to professional performance: The impact of CK and PCK on teaching quality in explaining situations. *Journal of Research in Science Teaching*, 55(10), 1393-1418. <https://doi.org/10.1002/tea.21457>
- Lai, E., & Lam, C.-C. (2011). Learning to teach in a context of education reform: Liberal studies student teachers' decision-making in lesson planning. *Journal of Education for Teaching*, 37(2), 219-236. <https://doi.org/10.1080/02607476.2011.558287>
- Leavy, A., & Hourigan, M. (2018). Using lesson study to support the teaching of early number concepts: Examining the development of prospective teachers' specialized content knowledge. *Early Childhood Education Journal*, 46(1), 47-60. <https://doi.org/10.1007/s10643-016-0834-6>
- Leshota, M., & Adler, J. (2018). Disaggregating a mathematics teacher's pedagogical design capacity. In L. Fan, L. Trouche, C. Qi, S. Rezat, & J. Visnovska (Eds.), *Research on mathematics textbooks and teachers' resources. ICME-13 Monographs* (pp. 89-117). Springer. [https://doi.org/10.1007/978-3-319-73253-4\\_5](https://doi.org/10.1007/978-3-319-73253-4_5)
- Leufer, N., Prediger, S., Mahns, P., & Kortenkamp, U. (2019). Facilitators' adaptation practices of curriculum material resources for professional development courses. *International Journal of STEM Education*, 6, Article 24. <https://doi.org/10.1186/s40594-019-0177-0>
- Lindmeier, A., Seemann, S., Kuratli-Geeler, S., Wullschleger, A., Dunekacke, S., Leuchter, M., Vogt, F., Opitz, E. M., & Heinze, A. (2020). Modelling early childhood teachers' mathematics-specific professional competence and its differential growth through professional development—an aspect of structural validity. *Research in Mathematics Education*, 22(2), 168-187. <https://doi.org/10.1080/14794802.2019.1710558>
- Maaß, K., & Artigue, M. (2013). Implementation of inquiry-based learning in day-to-day teaching: A synthesis. *ZDM – Mathematics Education*, 45(6), 779-795. <https://doi.org/10.1007/s11858-013-0528-0>
- Maass, K., Cobb, P., Krainer, K., & Potari, D. (2019). Different ways to implement innovative teaching approaches at scale. *Educational Studies in Mathematics*, 102(3), 303-318. <https://doi.org/10.1007/s10649-019-09920-8>
- Maier, M. S. (2018). Qualitative Methoden in der Forschungspraxis: Dateninterpretation in Gruppen als Black Box [Qualitative methods in research practice: Data interpretation in groups as a Black Box]. In M. S. Maier, C. I. Keßler, U. Deppe, A. Leuthold-Wergin, & S. Sandring (Eds.) *Qualitative Bildungsforschung. Methodische und methodologische Herausforderungen in der Forschungspraxis* [Qualitative Educational Research. Methodological and Epistemological Challenges in Research Practice] (pp. 29-49). Springer. [https://doi.org/10.1007/978-3-658-18597-8\\_3](https://doi.org/10.1007/978-3-658-18597-8_3)
- Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. In A. Bikner-Ahsbahr, C. Knipping, & N. Presmeg (Eds.), *Approaches to qualitative research in mathematics education* (pp. 365-380). Springer. [https://doi.org/10.1007/978-94-017-9181-6\\_13](https://doi.org/10.1007/978-94-017-9181-6_13)
- Morris, A. K., & Hiebert, J. (2011). Creating shared instructional products: An alternative approach to improving teaching. *Educational Researcher*, 40(1), 5-14. <https://doi.org/10.3102/0013189X10393501>
- Morris, A. K., Hiebert, J., & Spitzer, S. M. (2009). Mathematical knowledge for teaching in planning and evaluating instruction: What can preservice teachers learn? *Journal for Research in Mathematics Education*, 40(5), 491-529. <https://doi.org/10.5951/jresmetheduc.40.5.0491>
- Mulligan, J., & Mitchelmore, M. (2009). Awareness of pattern and structure in early mathematical development. *Mathematics Education Research Journal*, 21(2), 33-49. <https://doi.org/10.1007/BF03217544>
- Mulligan, J., Oslington, G., & English, L. (2020). Supporting early mathematical development through a 'pattern and structure' intervention program. *ZDM – Mathematics Education*, 52(4), 663-676. <https://doi.org/10.1007/s11858-020-01147-9>
- Prediger, S., & Selzer, C. (2024). Establish shared visions and support productive adaptations on all levels. *Implementation and Replication Studies in Mathematics Education*, 4(1), 15-49. <https://doi.org/10.1163/26670127-bja10020>
- Prediger, S., Roesken-Winter, B., Stahnke, R., & Pöhler, B. (2022). Conceptualizing content-related PD facilitator expertise. *Journal of Mathematics Teacher Education*, 25(4), 403-428. <https://doi.org/10.1007/s10857-021-09497-1>
- Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research*, 75(2), 211-246. <https://doi.org/10.3102/00346543075002211>
- Remillard, J. T., & Heck, D. J. (2014). Conceptualizing the curriculum enactment process in mathematics education. *ZDM – Mathematics Education*, 46(5), 705-718. <https://doi.org/10.1007/s11858-014-0600-4>
- Remillard, J., & Kim, O.-K. (2017). Knowledge of curriculum embedded mathematics: Exploring a critical domain of teaching. *Educational Studies in Mathematics*, 96(1), 65-81. <https://doi.org/10.1007/s10649-017-9757-4>
- Richter, A., Bruns, J., & Gasteiger, H. (2025). Interaction- or material-centred implementation of teacher professional development: A comparison of teachers' competence development and potential lesson planning. *Journal Für Mathematik-Didaktik*, 46(1), Article 8. <https://doi.org/10.1007/s13138-025-00259-7>

- Roesken-Winter, B., Stahnke, R., Prediger, S., & Gasteiger, H. (2021). Towards a research base for implementation strategies addressing mathematics teachers and facilitators. *ZDM – Mathematics Education*, 53(5), 1007-1019. <https://doi.org/10.1007/s11858-021-01220-x>
- Şahin-Gür, D., & Prediger, S. (2023). Facilitators' planning practices for PD activities and their alignment to chosen PD goals: A case study on relevance of unpacking PD goals. In P. Drijvers, C. Csapodi, H. Palmér, K. Gosztonyi, & E. Kónya (Eds.), *Proceedings of the Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13)* (pp. 4818-4825). Alfréd Rényi Institute of Mathematics and ERME.
- Schoenfeld, A. H. (2010). *How we think: A theory of goal-oriented decision making and its educational applications*. Routledge. <https://doi.org/10.4324/9780203843000>
- Schöner, P., & Benz, C. (2018). Visual structuring processes of children when determining the cardinality of sets: The contribution of eye-tracking. In C. Benz, A. S. Steinweg, H. Gasteiger, P. Schöner, H. Vollmuth, & J. Zöllner (Eds.), *Mathematics Education in the Early Years. Results from the POEM3 Conference, 2016* (pp. 123-144). Springer. [https://doi.org/10.1007/978-3-319-78220-1\\_7](https://doi.org/10.1007/978-3-319-78220-1_7)
- Seidel, T., Rimmel, R., & Prenzel, M. (2005). Clarity and coherence of lesson goals as a scaffold for student learning. *Learning and Instruction*, 15(6), 539-556. <https://doi.org/10.1016/j.learninstruc.2005.08.004>
- Splinter, S. E., Depaepe, F., Verschaffel, L., & Torbeyns, J. (2024). Perceptual subitizing performance in 3- and 4-year-olds: The impact of visual features of sets. *Journal of Experimental Child Psychology*, 244, Article 105946. <https://doi.org/10.1016/j.jecp.2024.105946>
- Sprenger, P., & Benz, C. (2020). Children's perception of structures when determining cardinality of sets—results of an eye-tracking study with 5-year-old children. *ZDM – Mathematics Education*, 52(4), 753-765. <https://doi.org/10.1007/s11858-020-01137-x>
- Wood, T. L., Nelson, B. S., & Warfield, J. (2001). *Beyond classical pedagogy: Teaching elementary school mathematics*. Erlbaum.
- Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE.