

# The role of opportunities to learn in early childhood teacher education from two perspectives: A multilevel model

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**Abstract** Early childhood teacher education is considered crucial for the development of professional knowledge. However, little is known about the impacts of teacher educators, especially with respect to domain-specific knowledge in areas like early mathematics education. We investigated the relationship between opportunities to learn as reported by teacher educators and perceived by pre-service teachers and pre-service teachers' general pedagogical knowledge, mathematics pedagogical content knowledge, and mathematical content knowledge. The sample comprised 909 pre-service teachers from two different teacher education tracks (vocational school vs. university) and their 43 teacher educators. The results provided the first empirical evidence that opportunities to learn reported by teacher educators are highly relevant for pre-service teachers' knowledge. This strengthens calls to focus on the role of teacher educators in both research and practice.

**Keywords** Early childhood teacher · Early mathematics education · Early childhood teacher education · Early childhood teacher educators · Opportunities to learn

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## Die Rolle von Lerngelegenheiten in der Ausbildung von frühpädagogischen Fachkräften aus zwei Perspektiven: Ein Mehrebenenmodell

**Zusammenfassung** Die Ausbildung von frühpädagogischen Fachkräften gilt als Ausgangspunkt für die Entwicklung von professionellem Wissen. Bislang ist wenig über die Rolle von Lehrkräften in der Ausbildung bekannt, insbesondere, wenn es um die Entwicklung von domänenspezifischem Wissen, z. B. zur frühen mathematischen Bildung geht. In der vorliegenden Studie untersuchen wir den Zusammenhang von Lerngelegenheiten, die von den Lehrkräften berichtet werden, Lerngelegenheiten, die von den Auszubildenden wahrgenommen werden und dem allgemein-pädagogische, mathematikdidaktischem und mathematischem Wissen. Die Studie basiert auf einer Stichprobe von 909 angehenden frühpädagogischen Fachkräften, die sowohl an der Fachschule für Sozialpädagogik als auch in kindheitspädagogischen Studiengängen ausgebildet werden und deren 43 Lehrkräften. Die Ergebnisse geben erste Hinweise, dass die von den Lehrkräften berichteten Lerngelegenheiten bedeutsam für das erreichte Wissen sind und stärken damit die Forderung in Forschung und Praxis die Rolle der Lehrkräfte stärker in den Blick zu nehmen.

**Schlüsselwörter** Erzieher\*Innen · Frühe mathematische Bildung · Erzieherausbildung · Erzieherausbilder\*Innen · Lerngelegenheiten

### 1 Introduction

Teacher education is seen as crucial for the development of pre-service teachers' professional knowledge and beliefs (Blömeke and Kaiser 2012) and high-quality early childhood education (Anders 2013; Kluczniok and Roßbach 2014). Teacher educators are responsible for implementing the intended curricula. However, the relationship between the opportunities to learn provided by teacher educators and pre-service teachers' actual learning—also known as the “attained” curriculum (Schmidt et al. 1997)—has only been sparsely investigated (e.g. Phuong et al. 2018). Moreover, little can be said about the extent to which pre-service teachers' perceptions of their opportunities to learn match what is reported by teacher educators. A difference might well exist. Therefore, the distinction between the “potentially” implemented curriculum and the actually implemented curriculum introduced in the TIMSS context with reference to school textbooks (Schmidt et al. 1997) may apply to the case of teacher education as well.

The lack of research on these relations between the potentially implemented, implemented and attained curriculum also applies to early childhood teacher education in the domain of mathematics. This is unfortunate, as researchers (e.g. Nguyen et al. 2016) and policymakers (KMK 2017; JMK and KMK 2004) have repeatedly emphasized the importance of early mathematics education, given the relevance of mathematics for later life outcomes and of early childhood education for educational success in school (Anders 2013). Moreover, the extent to which students are able

to develop mathematics knowledge during schooling seems to depend on what they have learned previously (Nguyen et al. 2016).

In the present study, we sought to provide empirical evidence on this research gap for the first time. We investigated opportunities to learn general pedagogical knowledge (GPK), mathematics pedagogical content knowledge (MPCK) and mathematical content knowledge (MCK) as reported by teacher educators and as perceived by pre-service teachers and linked them to achievement in these domains. Investigating opportunities to learn from different perspectives is both a question of validity and a substantive research question. Teacher educators' and pre-service teachers' perceptions on the extent to which curricula have been implemented do not necessarily need to match (McDonnell 1995). In fact, there are several reasons why they might differ: pre-service teachers' freedom to select which classes to enroll in, the two groups rating OTL relative to different expectations and benchmarks, or social desirability bias (e.g. overreporting by teacher educators or underreporting by pre-service teachers). Consequently, it is important to learn to what extent the perspectives differ (validity perspective).

At the same time, in order to improve future teacher education, it is important to learn which of the two perspectives is more strongly related to outcomes and whether there are differences across domains (e.g. GPK, MPCK and MCK) or teacher education tracks (substantive research question). The impact of opportunities to learn on pre-service teachers' outcomes might differ across different tracks of teacher education, such as vocational school vs. university, due to differences in the curriculum, learning setting, or teacher educators' qualifications.

Both university and vocational teacher education tracks exist in Europe (European Commission et al. 2019, p. 72), and the two tracks co-exist in German early childhood teacher education. Therefore, early childhood teacher education in Germany represents a good context in which to investigate the relationship between opportunities to learn reported by teacher educators, those perceived by pre-service teachers, and pre-service teachers' professional knowledge, all while comparing multiple tracks. The curricula in both tracks stipulate that pre-service teachers should develop GPK, which can be considered the core of German early childhood teacher education, as well as MPCK and MCK (KMK 2017; Robert Bosch Stiftung 2008). However, there are also differences between the two tracks regarding, for example, program specialization or the early childhood teacher educators' qualifications.

## 2 Theoretical background

### 2.1 Early childhood teacher education in Germany

Our study took place in the context of German early childhood teacher education. German early childhood teacher education is heterogeneous in a variety of aspects and reflects the wide range of possible ways to become an early childhood teacher in Europe (European Commission et al. 2014, p. 97). A number of countries have recently modified their early childhood teacher education, now requiring at least a bachelor's degree to work as an early childhood teacher (e.g., Switzerland). In

other countries, a postsecondary vocational qualification is the minimum requirement (e.g., Austria, Ireland: European Commission et al. 2019, p. 72).

In Germany these different tracks co-exist. There is a two- to four-year vocational track offered by specialized post-secondary institutions (vocational schools) (Oberhuemer et al. 2010). About 95% of German early childhood teachers are educated through this non-university track (Autorengruppe Fachkräftebarometer 2019). Additionally, a number of degree programs in early childhood education at universities of applied sciences have been established since 2004 (Oberhuemer et al. 2010). These university track programs typically award bachelor's degrees to their graduates. Students in the vocational track are grouped into sections, which typically stay together over the entire course of their education with a fixed curriculum and few electives. In contrast, university students have greater autonomy in choosing courses from a range of options within the curriculum.

Teacher education in the vocational track qualifies pre-service teachers to work with children and adolescents from early childhood to adolescence, with an age range from 0 to 18 (Bröring 2017). The Standing Conference of the Ministers of Education and Cultural Affairs provides only general national guidelines with respect to the curriculum for early childhood teacher education in the vocational track (KMK 2017). These general guidelines are then adapted by each federal state. Most states' curricula follow the general curriculum to a large extent. The general curriculum defines several competencies that pre-service teachers should develop during teacher education, such as collaboration in teacher networks, guiding transitions between different educational activities over the course of the day, or stimulating, supporting and promoting children's and adolescents' developmental and educational processes (KMK 2017). The latter competence includes domain-specific educational aspects in early childhood. Pre-service teachers should become socially competent professionals and gain domain-specific knowledge and skills. Nevertheless, the general curriculum is merely a broad description of to-be-covered topics that must be translated into concrete teacher education programs by the federal states, vocational schools and teachers.

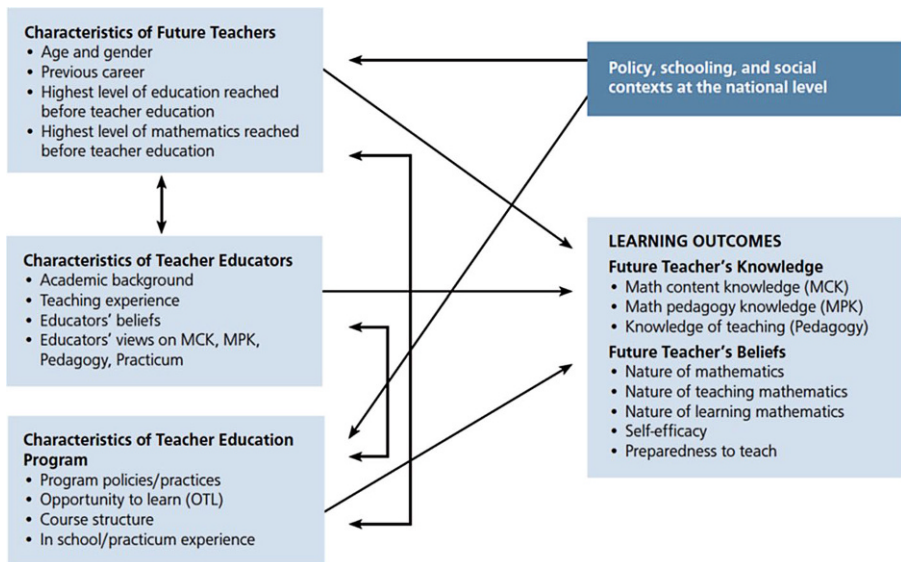
In contrast, teacher education in the university track is largely focused on topics related to *early* childhood, ages 0 to 6. The curriculum sometimes emphasizes specialized aspects, such as leadership of early childhood institutions (Bröring 2017). Another difference is that the university track promotes research-based knowledge and performance and therefore provides a foundation for graduates to integrate current empirical evidence into early childhood practice (Bröring 2017). The Robert Bosch Stiftung (2008) developed a qualification framework for early childhood teacher education in the university track. This qualification framework identifies a broad range of pedagogical and domain-specific topics that can be addressed in university-track early childhood teacher education. Like the vocational track, one of the aims of the university track is to develop pre-service teachers' social competence and professional knowledge in several domains.

In conclusion, while some differences exist between the two tracks with respect to their structure and implementation, both are intended to foster GPK, MCK and MPCK (KMK 2017; NAECTE 2009; Robert Bosch Stiftung 2008). In this study, we analysed the 16 federal states' curricula for the vocational track as well as all

available module syllabi for the university track (Blömeke et al. 2015). The content identified provides a comprehensive picture of the potential implementation of opportunities to learn in German early childhood teacher education (Jenßen et al. 2015). With respect to GPK, this content includes, for example, knowledge about children’s development or teacher-child interactions. MPCCK-related content includes, for example, knowledge about mathematical concepts and misconceptions that children experience in the course of their development as well as knowledge about specific instructional strategies, such as using everyday situations for mathematics learning. MCK refers to knowledge about the subject of mathematics; it includes knowledge from several content areas within mathematics as well as process-related knowledge. For example, pre-service teachers should develop knowledge about counting principles.

### 2.2 Impact of teacher education programs

Research on primary and secondary school teachers has revealed that the impact of teacher education programs on pre-service teachers’ learning depends on institutional characteristics of the teacher education institutions, individual characteristics of the pre-service teachers, and characteristics of the teacher educators (Blömeke et al. 2012; Tatto et al. 2008). Transferring this research to early childhood education, the following conceptual model can be developed: Institutional characteristics of early childhood teacher education include the type of program (e.g., vocational school vs. university) and the specific opportunities to learn (OTL) in terms of classes or teaching methods experienced. Pre-service teachers’ individual characteristics include their academic background in terms of high school grades, demographic



**Fig. 1** Hypothesized impact of teacher education programs in primary and secondary school teacher education. (Tatto et al. 2008, p. 14)

background and motives to become an early childhood teacher. Characteristics of teacher educators include their academic background, participation in professional development, demographic background and professional beliefs. Fig. 1 illustrates this model. While a designated theoretical model and empirical evidence specifically for the field of early childhood teacher education are lacking, we assume that the model of school teacher education can be applied to early childhood teacher education, as also suggested by Anders (2012).

The impact of opportunities to learn as perceived by pre-service early childhood teachers on the outcomes of teacher education has been investigated in several studies in recent years. A study by Blömeke et al. (2017b) showed by estimating Cronbach's alpha that pre-service early childhood teachers gave consistent reports on an interindividual level about their opportunities to learn during teacher education. This applied to the domains of GPK, MPCK, and MCK. Furthermore, it has been shown that domain-specific opportunities to learn affected pre-service teachers' knowledge (Blömeke et al. 2017b; Mischo 2016; Torbeyns et al. 2019) as well as their beliefs (Blömeke et al. 2017a; Mischo, Wahl, Strohmer and Wolf 2014). Research indicated that the effect of different educational tracks (vocational school vs. university) was mediated by domain-specific opportunities to learn as perceived by pre-service early childhood teachers (Blömeke et al. 2017b; Mischo et al. 2014). This means that in addition to institutional aspects, such as the type of teacher education track (vocational vs. university), process aspects such as the specific opportunities to learn need to be taken into account when estimating effects on pre-service teachers' learning (Blömeke et al. 2017b).

Based on the existing research, it can be concluded that opportunities to learn as perceived by pre-service teachers explain their attainment of professional knowledge. However, the relationship between teacher educators, who are responsible for implementing the intended opportunities to learn, and pre-service teachers' professional knowledge has been investigated less frequently. In a systematic review, Phoung et al. (2018) found evidence of a growing body of research on teacher educators in general around the world. However, there are a lack of quantitative studies and studies focusing on the relationship between teacher educators and domain-specific outcomes of teacher education (Phuong et al. 2018). This problem is even more evident for early childhood teacher education in the field of mathematics in Germany (Kleeberger and Stadler 2011; Spieß and Tietze 2002). To the best of our knowledge, there is only a single study by Kleeberger and Stadler (2011) was the only one addressing early childhood teacher educators in Germany. However, this study explored general aspects of early childhood teacher education, such as what materials were used for teacher education and whether internships were required.

Studies have shown that the implementation of new content within teacher education can depend on early childhood teacher educators' own professional development (Whyte et al. 2018). Specifically regarding early childhood teacher education in mathematics, Whyte et al. (2018) demonstrated that the role of teacher educators depended on their level of qualification. This assumption might hold true for early childhood teacher educators in Germany as well, and is linked to the question of how early childhood teacher educators are trained.

There are only six university programs training vocational-track early childhood teacher educators in Germany (Autorengruppe Fachkräftebarometer, 2019). While these programs address how to educate pre-service teachers so that they learn to support children's and adolescents' development of socio-emotional competencies, early mathematics education is typically not included in the curriculum. Therefore, teacher educators may have different types of qualifications and feel less prepared to teach early childhood mathematics (Kleeberger and Stadler 2011).

Beyond general aspects, like possession of a university degree, information about the training of university-track teacher educators is not available. Bröring (2017) assumes that one reason for the university tracks' aforementioned areas of specialization (see Sect. 2.1), alongside the higher level of autonomy afforded at this level, might be that university-track teacher educators have specific areas of expertise, such as leadership in early childhood education or early childhood mathematics education. These expertise profiles might impact the development of degree programs within the university track in general and their areas of specialization. This effect might be weaker for the knowledge domain of GPK, for which there is a more consistent curriculum across all institutions. Regarding MPCCK, however, pre-service teachers can choose among different opportunities to learn, depending on the specific teacher educator.

Research on the effects of early childhood teacher educators on pre-service teachers is still scarce, especially when it comes to domain-specific outcomes like professional knowledge in the field of mathematics (e.g., Phuong et al. 2018). Opportunities to learn offered by the teacher education institution and taken up by pre-service teachers have been discussed as a way to investigate the relationship between teacher educators and pre-service teachers (Praetorius et al. 2018).

### 2.3 Opportunities to learn in teacher education programs

Opportunities to learn have been examined in educational research for a long time. They are conceptualized as the degree to which a student has had the opportunity to learn a specific piece of content (McDonnell 1995). From this perspective, the official curriculum, which in Germany is typically stipulated by the (federal) state, can be seen as the intended curriculum. The *intended curriculum* describes what students should learn in an educational program. Teacher educators then implement the intended curriculum, which can be described as the "potentially implemented" curriculum (Schmidt et al. 1997), and pre-service teachers take advantage of the provided opportunities to learn, a process which is referred to as the *implemented curriculum*. This is in turn hypothesized to lead to certain outcomes, such as professional knowledge, which is known as the *attained* or *achieved curriculum* (McDonnell 1995).

Several transformation processes are assumed to occur between the intended, implemented, potentially implemented, and achieved curriculum (Ditton 2000). One of these concerns how the intended curriculum is implemented. In school effectiveness research, this question is often investigated by administering opportunities to learn questionnaires to teachers, as those who deliver content to school students (McDonnell 1995). In contrast, in teacher education research, questionnaires are more often

administered to pre-service teachers, as those who make use of the opportunities to learn (Blömeke et al. 2017b; Klemenz et al. 2019; Tatto et al. 2008). Research indicates that differences arise depending on whether opportunities to learn are measured on the individual level by surveying pre-service teachers or on the teacher education institution level by surveying teacher educators (Qian and Youngs 2016; Schmidt et al. 2011). These differences are driven by differences in the implementation of the curriculum by educational institutions and differences in the use of opportunities to learn by pre-service teachers. The former is therefore known as the “potentially” implemented curriculum. Obtaining data from both perspectives allows us to investigate the relationship between the implemented and potentially implemented curriculum, and when combined with data on pre-service teachers’ GPK, MPCK, and MCK, the relationship between the implemented and achieved curriculum (McDonnell 1995). In more technical terms, this means that opportunities to learn can be treated as an independent, a mediating or a dependent variable (McDonnell 1995; Praetorius et al. 2018).

### 3 Research questions

Early childhood teacher education in Germany takes place in two tracks: vocational school and university (Bröring 2017). The curricula for both tracks define pre-service teachers’ development of GPK, MPCK and MCK as an important objective (KMK 2017; Robert Bosch Stiftung 2008). The impact of teacher education may depend on a broad range of individual and institutional characteristics (Blömeke et al. 2012; Tatto et al. 2008). Opportunities to learn as reported by teacher educators or pre-service teachers have been identified as potential predictors as well (McDonnell 1995; Praetorius et al. 2018). While pre-service teachers’ perception of opportunities to learn has been investigated (Blömeke et al. 2017b; Mischo et al. 2013), less is known about how teacher educators perceive opportunities to learn in early childhood teacher education. Whyte et al. (2018) identified teacher educators as important stakeholders in implementing the curriculum, especially when it comes to new content.

In our study, we address this research gap by investigating the relationship between opportunities to learn as reported by teacher educators and as perceived by pre-service early childhood teachers. Additionally, we examine the relationship between opportunities to learn and outcomes of early childhood teacher education, namely pre-service teachers’ achieved professional knowledge. The opportunities to learn reported by early childhood teacher educators are used as an indicator for the potentially implemented curriculum. The opportunities to learn perceived by pre-service early childhood teachers are used as an indicator for individual use of opportunities to learn.

Therefore, a first research question is to what extent the opportunities to learn reported by teacher educators and perceived by pre-service teachers are related to each other and whether this relation differs by educational track (vocational school vs. university). Our hypothesis is that a significant positive relation with a substantial effect size exists. We further assume that the effects are smaller at universities



compared to vocational schools given pre-service teachers’ larger autonomy to select courses in the university track (H1). Secondly, we investigate the impact of opportunities to learn as reported by teacher educators on opportunities to learn as perceived by the pre-service early childhood teachers and on their achieved professional knowledge. Our hypothesis is that significant positive direct and indirect relations between opportunities to learn and professional knowledge exist (H2). For both hypotheses, we assume larger effect sizes for GPK and MPCK. GPK can be seen as the core domain of both teacher education tracks. If the impact of teacher education described above does exist for early childhood teacher education, it is most likely to be identified in the domain of GPK. Regarding MPCK, it seems that opportunities to learn are only offered in teacher education. For MCK, we assume smaller relations than for GPK and MPCK because some aspects of this knowledge area may already have been learned during primary and secondary schooling. MCK specifically focused on early childhood is usually part of teacher education programs only to a limited extent. We investigate H1 and H2 in three separate analyses for GPK, MPCK and MCK.

## 4 Methods

### 4.1 Participants and procedure

The present study is based on a sample of  $n = 909$  pre-service early childhood teachers from 43 classes in 25 teacher education institutions in Germany. It represents a subsample of the KomMa project (Blömeke et al. 2017b) for which additional information about opportunities to learn (OTL) as reported by teacher educators

**Table 1** Descriptive statistics for the total sample of pre-service teachers (pst) and the subsample

		<i>N</i>	<i>M (SD)</i>	<i>Min</i>	<i>Max</i>	<i>df</i>	<i>t</i>	<i>p</i>
OTL GPK (pst)	Total sample	923	3.07 (0.63)	1.00	4.00	1813	0.880	0.38
	Subsample	892	3.04 (0.60)	1.00	4.00			
OTL MPCK (pst)	Total sample	920	2.16 (0.84)	1.00	4.00	1800	1.710	0.09
	Subsample	882	2.10 (0.75)	1.00	4.00			
OTL MCK (pst)	Total sample	915	2.05 (0.83)	1.00	4.00	1800	0.852	0.39
	Subsample	890	2.02 (0.84)	1.00	4.00			
GPK	Total sample	935	50.13 (10.03)	19.88	75.65	1839	0.561	0.58
	Subsample	906	49.87 (9.97)	20.56	75.19			
MPCK	Total sample	940	50.13 (10.06)	14.45	73.55	1845	0.574	0.57
	Subsample	907	49.86 (9.94)	14.75	74.14			
MCK	Total sample	938	50.27 (9.59)	24.65	78.68	1844	1.173	0.24
	Subsample	908	49.72 (10.40)	20.05	78.68			

was available. Response rates of 48% for opportunities to learn in GPK, 43% for opportunities to learn in MPCK and 45% for opportunities to learn in MCK were achieved. Regarding our dependent variables, there were no significant differences in any knowledge domain or in reported opportunities to learn between our subsample and the total study sample of pre-service early childhood teachers (see Table 1). Trained project staff administered all tests and questionnaires during regular instructional time at the teacher education institutions. Participation was voluntary for pre-service teachers as well as teacher educators. Data collection took place during winter 2013/14.

A large majority of the subsample was female (86%; 14% male), which is in line with the population of pre-service early childhood teachers in Germany (Autorengruppe Fachkräftebarometer 2019). The participants' mean age was  $M=24$  years ( $SD=6$  years). A majority of the subsample was enrolled in a vocational-track program (707 pre-service teachers in 35 classes). Pre-service teachers in the vocational track differed from those in the university track in terms of schooling (only 44% had completed at least 12 or 13 years of school, while all pre-service teachers in the university track had completed at least 12 or 13 years of school). We found only limited differences between the vocational and university tracks for opportunities to learn GPK or MCK as perceived by the students, whereas university students reported more opportunities to learn MPCK with a medium effect size (see Table 2). With respect to teacher educators, differences between those at vocational schools

**Table 2** Descriptive statistics for pre-service teachers (pst) trained at the vocational and university level

		<i>N</i>	<i>M (SD)</i>	<i>Min</i>	<i>Max</i>	<i>df</i>	<i>t</i>	<i>p</i>	<i>d</i>
OTL GPK (pst)	Vocational	694	3.04 (0.61)	1.00	4.00	890	-0.353	0.72	-
	University	198	3.06 (0.55)	1.50	4.00				
OTL MPCK (pst)	Vocational	686	2.00 (0.67)	1.00	3.86	260	-6.345	0.00	0.61
	University	196	2.44 (0.90)	1.00	4.00				
OTL MCK (pst)	Vocational	693	2.00 (0.80)	1.00	4.00	283	-1.650	0.10	-
	University	197	2.11 (0.94)	1.00	4.00				
GPK	Vocational	705	48.23 (9.52)	22.23	75.19	904	-9.741	0.00	0.78
	University	201	55.62 (9.39)	20.56	75.19				
MPCK	Vocational	705	48.27 (9.66)	14.75	74.14	905	-9.440	0.00	0.75
	University	202	55.42 (8.88)	24.10	72.53				
MCK	Vocational	706	47.87 (9.89)	20.05	78.68	906	-10.632	0.00	0.85
	University	202	56.20 (9.55)	33.65	78.68				

**Table 3** Descriptive statistics for teacher educators (te) at the vocational and university level

		<i>N</i>	<i>M (SD)</i>	<i>Min</i>	<i>Max</i>	<i>df</i>	<i>t</i>	<i>p</i>
OTL GPK (te)	Vocational	33	3.05 (0.72)	1.50	4.00	38	0.173	0.86
	University	7	3.00 (0.84)	1.75	4.00			
OTL MPCK (te)	Vocational	28	1.93 (0.68)	1.00	3.43	8.34	-1.775	0.11
	University	8	2.71 (1.20)	1.00	4.00			
OTL MCK (te)	Vocational	31	1.95 (0.80)	1.00	4.00	36	0.383	0.70
	University	7	1.82 (0.87)	1.00	3.00			

and those at universities were limited concerning all three aspects (see Table 3). However, we found significant differences with large effect sizes between the two tracks regarding pre-service teachers' GPK, MPCK and MCK (see Table 2).

## 4.2 Measures

### 4.2.1 Measures of opportunities to learn on the pre-service teacher level

Opportunities to learn regarding GPK, MPCK and MCK as perceived by pre-service teachers were assessed with questionnaires developed within the KomMa project (Blömeke et al. 2017b). All items' content was derived from a content analysis of early childhood teacher education curricula. The items cover typical aspects of various domains within early childhood teacher education. All items were rated on a four-point Likert scale from "1=not at all" to "4=intensely".

The scale assessing pre-service teachers' opportunities to learn GPK consisted of four items. An example item is "To what extent has knowledge about methods in early childhood been addressed in your teacher education until now? (e.g., educational principles)". The scale showed a good reliability of Cronbach's  $\alpha=0.73$  in the subsample used for this study. A typical item for the scale assessing pre-service teachers' opportunities to learn MPCK was "To what extent has knowledge about the development of number sense in early childhood been addressed in your teacher education until now? (e.g., aspects of the number concept)". The scale consisted of four items and showed a good reliability of Cronbach's  $\alpha=0.83$  in the present subsample. The scale regarding pre-service teachers' opportunities to learn in MCK consisted of seven items and also showed a good reliability of Cronbach's  $\alpha=0.91$  in the subsample. An example item is "To what extent did knowledge about numbers and operations occur in your teacher education until now? (e.g., Algebra)". All reliability coefficients for the opportunities to learn scales in the subsample are of comparable size to those in the total sample (Blömeke et al. 2017b).

### 4.2.2 Measures of opportunities to learn on the teacher educator level

The teacher educators answered the same questionnaire, with the difference that all questions asked whether the corresponding topic had been taught to the assessed class (e.g., "To what extent has knowledge about methods in early childhood been addressed in teacher education for the assessed class until now? (e.g., educational principles)"). The questionnaire achieved good reliability among the teacher educators, comparable to that for the pre-service teachers ( $\alpha_{OTL\ GPK(te)}=0.77$ ,  $\alpha_{OTL\ MPCK(te)}=0.87$ ,  $\alpha_{OTL\ MCK(te)}=0.95$ ).

### 4.2.3 Measures of professional knowledge

Professional knowledge was assessed with standardized tests developed within the KomMa project (Blömeke et al. 2015). The validity of these tests are well documented (e.g., Blömeke et al. 2015, 2017b; Jenßen et al. 2019). GPK was assessed with an 18-item test covering aspects of educational theory as well as educational

Some children in your group are playing a strategy game. When they are done, you talk to those who lost and you inquire about their reasoning about why they lost.

Child A: „I was just unlucky“  
 Child B: I was not that interested in the game.“  
 Child C: „I do not understand this type of game.“

Which child provides a reason that is particularly unfavorable from a motivational point of view?  
 Child \_\_\_\_


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You are playing a dice game with three children. Please explain, in short, why their mathematical learning in the following field is fostered: **Numbers and operations (e.g., calculating):**

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 Chris has a blue, a green, a red and a yellow cube. Chris wants to pile up a tower with the four cubes.

Which arithmetic expression provides the number of possibilities of the different towers?  
 Please indicate your answer with a cross

- $4 + 4 + 4 + 4$
- $4 * 4 * 4 * 4$
- $4 * 3 * 2$
- $4 + 3 + 2$

**Fig. 2** Example items for (from top to bottom) general pedagogical knowledge, mathematics pedagogical content knowledge, and mathematical content knowledge

methods used in early childhood education. The MPCK test consisted of 28 items capturing aspects of children’s mathematical development and math-specific methods for supporting this development in early childhood education. The test assessing MCK consisted of 24 items covering core mathematical content domains (e.g., numbers and operations, measurement). Example items for all tests are given in Fig. 2.

All tests comprised both multiple choice and open response items, which were coded dichotomously (right or wrong). For the open response items, trained coders double-coded 20% of the answers. The interrater reliabilities were satisfactory ( $M_{\kappa\text{GPK}} = 0.76$ ,  $M_{\kappa\text{MPCK}} = 0.73$ ,  $M_{\kappa\text{MCK}} = 0.78$ ). For GPK, MPCK and MCK, we used scores based on a two-parameter logistic item response theory model (2PL IRT) transformed to have a mean of 50 and a standard deviation of 10, estimated with data from the total sample of the KomMa project (Blömeke et al. 2015, 2017b). Test reliability for these scores was estimated following the method by Raykov et al. (2010), and achieved satisfactory to good results ( $P_{\gamma\text{GPK}} = 0.68$ ,  $P_{\gamma\text{MPCK}} = 0.87$ ,  $P_{\gamma\text{MCK}} = 0.88$ ).

### 4.3 Data analysis

To answer our research questions, we estimated multilevel mediation models with *Mplus 8.1* (Muthén and Muthén 2017). We used robust maximum likelihood estimators (MLR estimators) and handled missing data with the full information maximum likelihood procedure implemented in *MPlus*.

We included the opportunities to learn scores for teacher educators and pre-service teachers as manifest variables. For the three knowledge variables, we used

**Table 4** Model fit of the multilevel mediation path models examining effects of opportunities to learn reported by teacher educators and students on pre-service teachers’ knowledge

Model	<i>N</i>	$\chi^2$	<i>df</i>	<i>p</i>	<i>RMSEA</i>	<i>CFI</i>	<i>SRMR</i> <i>w/b</i>
OTL GPK (te), OTL GPK (pst), GPK	899	7.431	4	0.11	0.03	0.97	0.02/0.09
OTL MPCK (te), OTL MPCK (ST), MPCK	899	6.062	4	0.19	0.02	0.98	0.03/0.09
OTL MCK (te), OTL MCK (pst), MCK	899	5.444	4	0.24	0.02	0.99	0.03/0.10

*GPK* general pedagogical knowledge, *MPCK* mathematics pedagogical content knowledge, *MCK* mathematics content knowledge, *w/b* within/between

the transformed manifest scores derived from the 2PL model mentioned above. Since pre-service teachers were nested within teacher educators and intraclass correlations (ICC) between the dependent variables were substantial (0.14 to 0.35), we decided to apply multilevel modelling. Manifest correlations for the variables are given in Appendix, Table 5 (within variables) and Appendix, Table 6 (between variables). Given the relatively small sample size on the between level, we estimated separate models for GPK, MPCK and MCK to limit the number of parameters to be estimated.

The effects of opportunities to learn reported by teacher educators were estimated as cross-level effects. This was done because each teacher educator was asked about the opportunities to learn provided to his or her class. The effect of opportunities to learn perceived by pre-service teachers was modelled on the within level, as we assume that perception and use of opportunities to learn may differ between pre-service teachers within a class, particularly in the university track. To represent differences in professional knowledge, we controlled for the pre-service teachers’ gender, language spoken at home and level of schooling in the analyses.

To check the robustness of our analysis, we estimated additional multi-group models (MGM) for pre-service early childhood teachers trained in the vocational and university track. Multi-group models allow effects to be compared across groups. We used the KNOWNCLASS option in *Mplus*, which enables all effects, including indirect effects, to be estimated separately for each group (vocational vs. university track) (Muthén and Muthén 2017). An additional advantage of this option is that it allows for estimating whether or not differences between groups are significant using the MODEL CONSTRAINT command (Muthén and Muthén 2017). The nested structure of the data was taken into account by using TYPE IS MIXTURE COMPLEX in the analysis (Muthén and Muthén 2017).

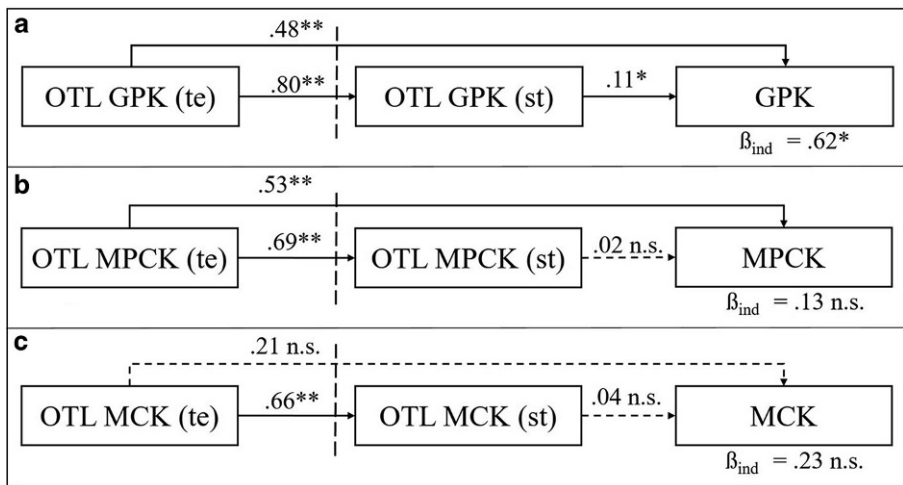
## 5 Results

### 5.1 Relationship between opportunities to learn reported by teacher educators and pre-service teachers

Fig. 3a–c provide information about the three multilevel mediation path models estimated separately for GPK, MPCK and MCK. All models showed a good model fit (see Table 4). Regarding our first hypothesis (H1), we found substantial and significant relationships between opportunities to learn reported by teacher educators and those perceived by pre-service teachers ( $\beta_{GPK/MPCK/MCK} = 0.80^{**}/0.69^{**}/0.66^{**}$ ).

### 5.2 Relationship between opportunities to learn and professional knowledge

H2 addressed the relationships between opportunities to learn in GPK, MPCK and MCK reported by teacher educators, those perceived by pre-service teachers, and pre-service teachers' achieved professional knowledge. The results are presented in Fig. 3a–c. For the domain of GPK, all coefficients were significant, including the indirect effect. The effect of opportunities to learn GPK as perceived by pre-service teachers was small ( $\beta = 0.11^*$ ). All other paths exhibited substantial effect sizes. Opportunities to learn GPK as reported by teacher educators explained 64.1% ( $p < 0.01$ ) of the variance in opportunities to learn in this area as perceived by pre-service teachers and 39.6% ( $p < 0.01$ ) of the variance in achieved GPK. Opportunities to learn as reported by pre-service teachers explained a further 9.1% ( $p < 0.01$ ) of the variance in this knowledge domain.



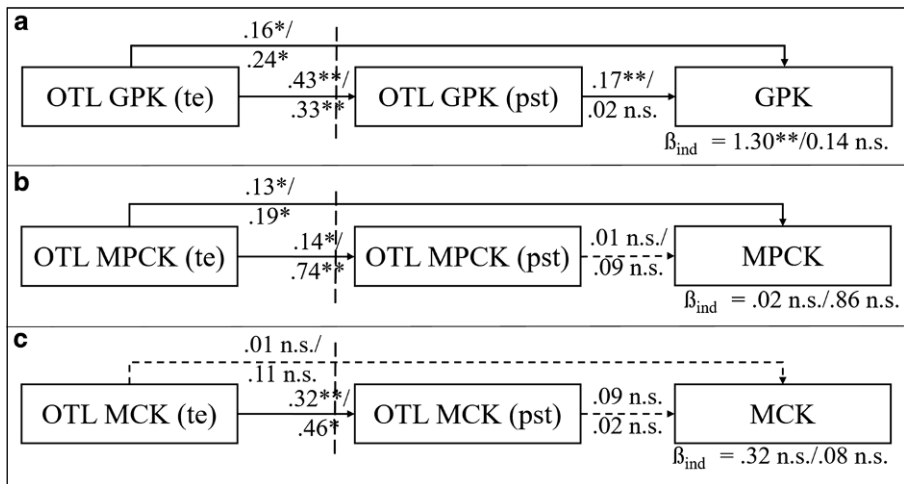
**Fig. 3** a–c Multilevel mediation models of the relationship between opportunities to learn as reported by teacher educators, those perceived by pre-service teachers and professional knowledge. *Note:* OTL opportunities to learn, GPK general pedagogical knowledge, MPCK mathematics pedagogical content knowledge, MCK mathematical content knowledge, te teacher educators, pst pre-service teachers, \* $p < 0.05$ , \*\* $p < 0.01$ , dotted line separates the between (left side) and within (right side) levels. Control variables (on GPK/MPCK/MCK): gender, language spoken at home, level of schooling

For MPCK, opportunities to learn as reported by teacher educators significantly affected MPCK ( $\beta = 0.53^{**}$ ). However, we found no significant relationship between opportunities to learn as perceived by pre-service teachers and their achieved MPCK. This also means that there was no significant indirect effect in this model. Opportunities to learn MPCK as reported by teacher educators explained a significant amount of the variance in opportunities to learn as perceived by pre-service teachers (47.1%,  $p < 0.01$ ) as well as in achieved MPCK (32.1%,  $p < 0.05$ ). On the individual level, 9.4% ( $p < 0.01$ ) of the variance in this knowledge domain could be explained.

Lastly, we estimated the multilevel mediation path model for MCK. The path coefficients only revealed a significant relationship between opportunities to learn MCK reported by teacher educators and those perceived by pre-service teachers. The within-level path between opportunities to learn and achieved MCK was not significant. This might indicate that the explained amount of within-level variance in MCK (22.3%,  $p < 0.01$ ) was due to the control variables. Opportunities to learn as reported by teacher educators did not significantly explain variance in knowledge (8.6%,  $p = 0.38$ ) in this model. However, they explained 43.5% ( $p < 0.01$ ) of the variance in opportunities to learn as perceived by pre-service teachers.

### 5.3 Robustness check of the results

To check the robustness of our estimates, we also applied the three analyses as multi-group models (vocational vs. university track). The results are presented in Fig. 4a-c. The robustness check confirmed the aforementioned significant relation-



**Fig. 4 a-c** Multi-group model of the relationship between opportunities to learn reported by teacher educators, those perceived by pre-service teachers and professional knowledge. Note: Path coefficients: vocational track/university track; *OTL* opportunities to learn, *GPK* general pedagogical knowledge, *MPCK* mathematics pedagogical content knowledge, *MCK* mathematical content knowledge, *te* teacher educators, *pst* pre-service teachers, \* $p < 0.05$ , \*\* $p < 0.01$ , dotted line separates the between (left side) and within (right side) levels. Control variables (on GPK/MPCK/MCK): gender, language spoken at home, level of schooling

ships between opportunities to learn reported by teacher educators and those perceived by pre-service teachers (H1). However, the coefficient for opportunities to learn MPCK was significantly ( $p < 0.001$ ) larger in the university track. For GPK and MCK, the difference between the two tracks was not significant ( $p = 0.53/0.61$ ).

For the domain of GPK, the relationship between opportunities to learn perceived by pre-service teachers and achieved knowledge was only significant in the vocational track, not in the university track. However, the relationship did not differ significantly between the two tracks ( $p = 0.06$ ). For the domains of MPCK and MCK, the relational structure was similar to the model estimated for the overall sample. There were no significant differences between the vocational and university tracks in the structure of the relationship between opportunities to learn MPCK reported by teacher educators and those perceived by pre-service teachers.

## 6 Discussion, limitations and conclusion

### 6.1 Discussion

Our study investigated the relationship between opportunities to learn GPK, MPCK and MCK as reported by teacher educators (also known as the “potentially” implemented curriculum, in line with the TIMSS literature; Schmidt et al. 1997), those perceived by pre-service early childhood teachers (implemented curriculum) and outcomes of teacher education in terms of professional knowledge in the three domains (attained curriculum). Thus, this study addressed a frequently criticized research gap concerning the role of teacher educators in early childhood teacher education in mathematics (e.g., Phuong et al. 2018; Whyte et al. 2018).

In line with our first hypothesis, we found strong relationships between the two ways of measuring opportunities to learn in all three domains (GPK, MPCK, MCK). This provides first evidence that teacher educators and pre-service teachers in early childhood teacher education identify similar amounts of opportunities to learn, unlike teacher educators and pre-service teachers in primary school teacher education (Qian and Youngs 2016; Schmidt et al. 2011). We interpret this finding as an indicator that early childhood teacher educators tend to succeed in making opportunities to learn clear to pre-service teachers. Thus, they lay the foundation for learning processes as described in models of teacher education (Blömeke et al. 2010; McDonnell 1995; Praetorius et al. 2018).

We found a similar pattern when estimating the effects separately for the two tracks of early childhood teacher education (vocational school vs. university). Only one expectation was formulated, namely a significantly stronger relationship between opportunities to learn MPCK as reported by teacher educators and pre-service teachers in the university track. Due to students’ larger autonomy to select classes at university, we had assumed weaker effect sizes here. This finding is even more surprising in light of the fact that some university programs focus on specialized aspects such as leadership in early childhood institutions. Nevertheless, early mathematics education is potentially implemented in the core curriculum also in this case (Robert Bosch Stiftung 2008) and also in recent module syllabi (Blömeke et al.



2015). We can only speculate as to the cause of this to some extent unexpected result. One possible explanation might be that in the university track in Germany, MPCK is mostly taught in courses specifically addressing early mathematics education by a teacher educator specializing in this field (Bröring 2017). In the vocational track, by contrast, the topic is usually not clearly linked to a specific teacher educator or course (Kleeberger and Stadler 2011) and sometimes addressed in combination with early science education (KMK 2017). This means that opportunities to learn may be easier to perceive in the former than in the latter.

Mischo (2017) reports that about 59% of university-trained professionals are able to find a job in accordance with their qualifications after graduation, for example, one including a leadership role. Research in the domains of early science and language education has indicated that professional exchange among staff members contributes to strengthening domain-specific education within early childhood institutions (for science: Barenthien et al. 2019) and to improving the domain-specific quality of early childhood education (for language: Resa et al. 2018). In general, the role of head teachers with respect to the educational mandate is becoming increasingly emphasised (Ballaschk et al. 2017). For this reason, we argue that basic knowledge regarding aspects such as MPCK would be important for early childhood teachers trained in the university track.

Our second research question addressed the relation between opportunities to learn and knowledge. Our hypothesis was that significant positive direct and indirect relations between opportunities to learn and professional knowledge exist, especially for GPK and MPCK. For the domain of GPK, the hypothesized model was supported by our data. Moreover, we affirmed the robustness of our results by estimating the models separately for pre-service teachers in the vocational track and the university track, as we found a similar structure and no significant differences between the two groups.

This is important for several reasons. First, it highlights the relevance of teacher educators for the implementation of the intended curriculum. Furthermore, it confirms the relevance of pre-service teachers' utilization of opportunities to learn for their professional knowledge development. In addition, the strong indirect effect indicates that pre-service teachers' perceptions of opportunities to learn also play a crucial role. They perceive and make use of opportunities to learn based on their individual needs. However, the strong direct effect in the domain of GPK lends support to the notion that more focus should be placed on reports by teacher educators in early childhood education rather than solely on pre-service teachers' characteristics. This has also been emphasized in recent literature (Swennen et al. 2010; Whyte et al. 2018).

For the domain of MPCK, the results likewise indicate a strong relationship between opportunities to learn as reported by teacher educators and those perceived by pre-service teachers. However, in contrast to GPK, opportunities to learn MPCK as perceived by pre-service early childhood teachers did not affect achieved MPCK, nor was there an indirect effect. The same structure was identified when estimating the models separately for pre-service early childhood teachers in the vocational and university tracks. This was contrary to our hypothesis.

Two possible explanations for this result should be discussed: a lack of standardization and a lack of professional development. It is known from existing research that strict standards support the implementation of new topics (Whyte et al. 2018). Standards for the implementation of MPCK in German early childhood teacher education take the form of a national curriculum for the vocational track (KMK 2017) and of general recommendations for the university track (Robert Bosch Stiftung 2008). However, these standards are very general in nature, which might compromise their implementation. Furthermore, little is known about how these standards are applied in teacher education and, as we have shown above, how transformation processes occur or whether they need more time to emerge. Another explanation concerns the necessity of professional development for teacher educators so that they can implement new or domain-specific issues in teacher education. Existing research indicates that teacher educators are quite heterogeneous with regard to their own professional development, especially when it comes to domain-specific aspects in early childhood teacher education (Whyte et al. 2018). It can be assumed that early mathematics education is not a focus of professional development for early childhood teacher educators in Germany (Kleeberger and Stadler 2011), which might lead to problems when teaching this topic to pre-service teachers. Only six university degree programs exist in Germany specifically for vocational-track teacher educators in early childhood education (Autorengruppe Fachkräftebarometer 2019), most of which do not address early mathematics education. This might result in a higher rate of out-of-field teaching.

However, as with GPK, one can also see also for MPCK that opportunities to learn as reported by teacher educators directly explained variance in pre-service teachers' knowledge. This is a new finding, as opportunities to learn reported by teacher educators were not considered in earlier research (Blömeke et al. 2017b). Based on this result, we recommend investigating the role of teacher educators in early mathematics education more closely in the future—for example, to learn more about how they could support pre-service teachers in acquiring knowledge.

Lastly, the results showed that for the domain of MCK, only the path between opportunities to learn as reported by teacher educators and those perceived by pre-service teachers was significant; the paths to knowledge outcomes were not. The same structure was found when estimating the models separately for pre-service teachers from the vocational and university tracks. We know from the literature that MCK, especially in the vocational track, is taught similarly to secondary school mathematics (KMK 2017). In contrast, the MCK test in our study addressed content knowledge related to mathematics in early childhood (Blömeke et al. 2015; Jenßen et al. 2019). Based on earlier research, it can be assumed that such MCK is not at all addressed in early childhood teacher education (Whyte et al. 2018).

The descriptive results indicated that professional knowledge significantly differed for pre-service teachers in the vocational and university tracks. In contrast, their perceived opportunities to learn did not differ significantly. These results become more plausible when considering the results regarding the relationship between opportunities to learn reported by teacher educators, those perceived by pre-service teachers and knowledge. An explanation might be that differences in professional knowledge are driven by differences in opportunities to learn provided by teacher

educators. However, it remains an open question why pre-service teachers were not able to perceive these. An alternative explanation would be that the two groups enter teacher education with different levels of prior knowledge and basic cognitive abilities given the differences in entry requirements, as demonstrated by the differential length of schooling described in Sect. 4.1.

## 6.2 Limitations

When interpreting the results, several limitations of our study should be noted. First, our data is of a correlational nature and therefore does not allow for causal claims. The results only provide first evidence for the relationships between opportunities to learn reported by teacher educators, those perceived by pre-service teachers and professional knowledge. Secondly, we have no additional data on the teacher educators, such as their own qualifications and professional development, even though prior research has identified them as a heterogeneous group (Douglas 2017; Swennen et al. 2010), which might have affected our results. Third, one should note that the same applied to the pre-service teachers, as we lacked a measure of their initial level of knowledge. Moreover, the results for pre-service teachers in the university track were based on a limited sample size on the class level.

Lastly, a number of limitations concern the measures of opportunities to learn. One should keep in mind that the reliability of the scale measuring opportunities to learn GPK was not as high as that of the other two scales. One reason might be greater homogeneity among pre-service early childhood teachers regarding the perception of opportunities to learn GPK, as reflected in the low standard deviation. As already mentioned, GPK is a core topic in all early childhood teacher education institutions, while MPCK and MCK are typically not addressed. Furthermore, all data on opportunities to learn were based on self-reports by the teacher educators and pre-service early childhood teachers. For pre-service teachers, earlier research based on the project's total sample has provided first indications of the validity of score interpretations, which are linked to outcomes in terms of knowledge and beliefs (Blömeke et al. 2017a, b). However, further validation of the opportunities to learn scales—through direct observations, for example—would be helpful in order to better interpret our results. Lastly, one should keep in mind that we were only able to measure the quantity of opportunities to learn as opposed to the type and quality. From the perspective of teaching and learning in institutional settings, the type and quality of opportunities to learn might also impact outcomes (Klemenz et al. 2019; Praetorius et al. 2018; Whyte et al. 2018).

## 7 Conclusion

To our knowledge, our study was one of the first to investigate the relationship between opportunities to learn reported by early childhood teacher educators and those perceived by pre-service early childhood teachers, specifically concerning early mathematics education in German early childhood teacher education. Our results indicate that it might be useful to focus more on teacher educators in research on

early childhood teacher education in order to improve its quality and outcomes. This is particularly salient given that early childhood teacher education has been found to be of limited effectiveness with respect to domain-specific outcomes (Blömeke et al. 2017a; Torbeyns et al. 2019).

The results also support placing a stronger focus on teacher educators in early childhood teacher education. Specifically, opportunities to learn reported by teacher educators predicted professional knowledge *directly* as well as *indirectly* in the case of GPK. This leads to the question of whether teacher educators' reports might be a more valid source of information about the extent of opportunities to learn in teacher education, despite the strong relationship between opportunities to learn reported by teacher educators and those perceived by pre-service teachers. One possible explanation for this finding could be that teacher educators have experience with multiple cohorts of pre-service teachers due to their years of experience in teacher training. In contrast, pre-service teachers might ground their perceptions of opportunities to learn solely on their experiences in their own courses in relation to their expectations. Furthermore, pre-service teachers may not have been able to fully recognize the conceptual labels used in our questionnaire as corresponding to what they are learning in teacher education.

An open question arising from our results concerns what teacher education or teacher educators can do to strengthen the link between opportunities to learn perceived by pre-service early childhood teachers and their professional knowledge, especially with respect to MPCK. This question becomes even more important when considering that early childhood teacher education curricula in the domain of mathematics often are very general and in many cases voluntary in nature. For future research, it might be useful to focus more on the type and quality of opportunities to learn in addition to their quantity. Examining the type of opportunities to learn addresses the question of whether certain methods, such as inquiry-based learning, are more useful for helping pre-service teachers acquire knowledge. Quality is an important topic in research on school effectiveness (Praetorius et al. 2018), but empirical results and theoretical discourse (Eubanks-Turner 2020; Phuong et al. 2018) indicate that it might be an important issue in teacher education as well. This is further supported by the fact that we found only limited differences in the relationship between opportunities to learn and knowledge between the vocational and university tracks.

The question of teaching quality is linked to teacher educators' professional development. This might include structural aspects, such as teacher educators' formal qualifications (Whyte et al. 2018), but also aspects of teacher educators' professional competence, such as their beliefs or their own professional knowledge (Whyte et al. 2018). Given that MPCK often can be an optional topic in early childhood teacher education and early childhood teacher educators felt less prepared to teach topics in this area (Kleeberger and Stadler 2011), professional development is one opportunity to strengthen early mathematics education within teacher education.

For the domain of MCK, the pattern of results was not as clear as for the other two domains. However, there is an ongoing discussion concerning the content knowledge needed in early childhood education (Gasteiger and Benz 2018; Jenßen et al. 2019), which should be continued in upcoming years. This is not only relevant from

a theoretical perspective, as a means of learning more about how to support pre-service teachers' learning, but also from a practical point of view, as MCK has been discussed as a prerequisite for MPCK in early childhood teacher education (Dunekacke et al. 2016; Jenßen, Eid, Szczesny, Eilerts and Blömeke 2021).

In summary, this study's results provide first evidence that it might be useful for future research to focus on teacher educators in addition to pre-service teachers, because the former play a central role in teacher education, in accordance with prior theorizing (Phuong et al. 2018; Swennen et al. 2010; Whyte et al. 2018).

## Appendix

**Table 5** Manifest correlations for within variables

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Pre-service teachers Gender <sup>a</sup>	-0.07*	-0.02	-0.02	-0.02	0.01	0.01	-0.01	0.15**
(2) Language spoken at home	-	0.10**	0.04	0.01	-0.01	-0.01	-0.07*	-0.05
(3) Level of schooling	-	-	0.00	0.08*	-0.05	0.31**	0.31**	0.43**
(4) OTL GPK (pst)	-	-	-	0.30**	0.19**	0.19**	0.13**	0.08*
(5) OTL MPCK (pst)	-	-	-	-	0.53**	0.09**	0.15**	0.11**
(6) OTL MCK (pst)	-	-	-	-	-	0.01	0.06	0.07*
(7) GPK	-	-	-	-	-	-	0.46**	0.36**
(8) MPCK	-	-	-	-	-	-	-	0.46**
(9) MCK	-	-	-	-	-	-	-	1

<sup>a</sup> 0 = female, 1 = male

\* $p < 0.05$ , \*\* $p < 0.01$

**Table 6** Manifest correlations for between variables

	(2)	(3)
(1) OTL GPK (te)	0.34*	0.27
(2) OTL MPCK (te)	-	0.49**
(3) OTL MCK (te)	-	1

\* $p < 0.05$ , \*\* $p < 0.01$

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**Conflict of interest** S. Dunekacke, L. Jenßen and S. Blömeke declare that they have no competing interests.

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