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Cognitive, educational and psychological determinants of prospective preschool teachers' beliefs

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ABSTRACT

This study examined the level, structure and cognitive, educational and psychological determinants of beliefs about the relevance and nature of mathematics, about gender-stereotypes with respect to mathematics abilities and about enjoyment of mathematics. Prospective preschool teachers from programs at vocational schools and higher education institutions as well as in the first and last years of their programs were compared. As hypothesized, the beliefs were significantly correlated to each other which pointed to a coherent belief system. Differences between types of institutions and program stage supported the notion of development during the program. Knowledge of mathematics and opportunities to learn mathematics pedagogy were significantly related to beliefs. This may point to a need to include these domains in preschool teacher education or to require them as prerequisites before intake to a program. Gender-stereotypes were more strongly related to flexibility than to domain-specific predictors which points to the personality-related nature of beliefs.

KEYWORDS

Preschool teacher; teacher education; teacher knowledge; personality; mathematics

Introduction

Policy efforts to strengthen the quality of preschool have given rise to research on preschool teacher education and its outcomes. Preschool teachers' beliefs can be regarded an important precondition for their performance in preschool given the popular saying 'where there is no will, there is no way'. Evidence suggests indeed a significant relation of teacher beliefs to instructional quality and student achievement in particular in the field of mathematics (Stipek et al. 2001). If primary teachers believed that mathematics is a dynamic tool that offers children the possibility to discover and try out things, instructional activities of higher quality were implemented than if teachers believed in a more static nature of mathematics. Such differences in teacher beliefs also predicted differences in student achievement (Staub and Stern 2002).

Specifically with respect to preschool teachers, Kluczniok, Anders, and Ebert (2011) were able to show that teachers' beliefs had a significant impact on children's early mathematical literacy mediated by the activities implemented in preschool. Studies about

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mathematics-related beliefs of preschool teachers and what impacts them are very rare though although teacher beliefs may play an important role in the informal context of preschool. Preschool teachers need to become aware of opportunities to foster children's mathematics literacy in everyday situations (Lee and Ginsburg 2007) so that the filtering and guiding functions of beliefs may be relevant (see the conceptual framework below).

The research gap regarding preschool teachers' mathematics-related beliefs and what impacts them applies particularly to prospective teachers trained below the tertiary level. With a few exceptions such as Scandinavia or some states in the U.S.A., such preschool teachers still represent the majority in the U.S.A. (Bogard, Traylor, and Takanishi 2008) and many other countries (Wallet 2006) including Germany, which is the context of the present study. Preschool teacher education programs do in these cases take place at postsecondary or secondary vocational schools, and completion of high school is not necessarily a requirement.

A study was designed that allowed us to examine mathematics-related beliefs and their determinants with prospective preschool teachers from different programs and program stages: programs at vocational schools and higher education institutions and each time students in their first and their last year. Beliefs about the relevance and the nature of mathematics, about gender-stereotypes with respect to mathematics abilities and about enjoyment of mathematical activities were examined, thus covering cognitive and affective connotations of beliefs (Kelchtermans 2009). Furthermore, the impact of cognitive, psychological and educational characteristics of preschool teachers on these beliefs was examined.

Conceptual framework

Preschool teacher education in Germany

German preschool education can be subdivided into institutions covering 1- to 3-year-olds and institutions covering 3- to 6-year-olds (Blömeke et al. 2017). Teachers of the latter represent the target population of this study. At this age, more than 90% of the children are enrolled at least part-time although parents have to pay a small fee (Statistisches Bundesamt 2014). Preschools are not part of the school system but of the child and youth welfare system so that there is more emphasis on care than on formal education.

Play-based activities represent the norm for teacher–child interactions (Liegle 2008). Since more and more evidence points to the importance of child development before schooling for later student achievement (Duncan et al. 2007), the focus has shifted to fostering young children's cognitive development though – in particular with respect to 3- to 6-year-olds. All 16 German states have recently implemented standards for preschools that present ambitious cognitive objectives with respect to early reading, mathematics, and science literacy.

Preschool teachers are trained differently in the 16 German states. More than 90% are trained at vocational schools where the entrance requirement is not completion of high school but of 9 or 10 years of general schooling followed by 2 to 4 years of vocational training in a care profession. The 16 German states are responsible for the teacher education curricula at these schools. In parallel, 56 pedagogical colleges exist that are part of the higher education system and award a Bachelor degree. They have academic freedom to design their

curricula. Students must have completed high school followed by a 6 to 12-month pedagogical internship to enter college. Less than 10% of preschool teachers have undergone this type of education (Statistisches Bundesamt 2014).

(Prospective) preschool teachers' beliefs

Definition and conceptualization of beliefs

A precise definition of the term 'beliefs' as well as clear-cut differentiations from other concepts such as convictions, attitudes or perceptions, do not exist (Hofer and Pintrich 2002). Richardson (1996, 103) developed a widely-followed definition, in which beliefs are seen as 'psychologically held understandings, premises, or propositions about the world, that are felt to be true'. This definition was applied to the present study as well.

Beliefs are manifestations of an individual's experiences (Brownlee, Berthelsen, and Boulton-Lewis 2004). Besides affective components, beliefs consist to a varying degree of cognitive components so that it is sometimes difficult to distinguish between knowledge and beliefs (Kelchtermans 2009). Studies revealed that beliefs are relatively stable constructs against which teachers plan and implement their instructional activities (Op 't Eynde, De Corte, and Verschaffel 2002).

Beliefs function as bridges between teacher knowledge and performance in the classroom because they have an adaptive function in helping individuals to understand the world (Pajares 1992). They guide the perception and the interpretation of classroom situations and function, thus, as 'filters' (Fives and Buehl 2012). Beliefs are therefore crucial for the application of knowledge in classroom situations (Leder, Pehkonen, and Törner 2002).

The literature on teachers' mathematics-related beliefs typically distinguishes between beliefs about mathematics as a science and beliefs about the teaching and learning of mathematics (Thiel 2010). The present study follows this distinction and adds – similar to Benz (2012a) – a more affective-motivational facet to these merely cognitively connoted beliefs, namely enjoyment of mathematics. We follow thus Boekarts (1995) who requested taking motivational types of beliefs into account to 'bridge the gap between metacognitive and metamotivation theories'.

Beliefs seem to form discrete sets of interrelated concepts (Wehling and Charters 1969). Kagan (1992) argued therefore that teachers evolve a highly personalized belief *system* that constrains their perception, interpretation and behavior. Brownlee, Berthelsen, and Boulton-Lewis (2004) provided evidence for such a systematic relation with respect to child care staff's personal epistemological beliefs and their beliefs about teaching and learning.

Prospective preschool teachers' beliefs examined in this study

A basic belief and a precondition for implementing mathematical activities in preschool is the extent to which a (prospective) preschool teacher believes that mathematics is *relevant* for everyday life (also called an applied perspective on mathematics; Felbrich, Kaiser, and Schmotz 2012). Given the historical changes in preschool from an institution with a focus on care to an institution that increasingly puts weight on fostering cognitive development, more information about how strongly such a basic belief is pronounced in different groups of prospective preschool teachers and what impacts this belief is crucial.

The current state of research suggests that prospective and practicing preschool teachers still believe more strongly in their responsibility to foster socio-emotional than

cognitive development of children (Varol 2013) although they are generally convinced that children should develop early mathematical literacy during preschool (Chen et al. 2014). Benz (2012b) described this ambivalence as 'mathematics between appreciation and distance'.

In which way mathematical activities are implemented in preschool may depend on preschool teachers' beliefs about the *nature* of mathematics (Furinghetti and Pehkonen 2002). A typical dimension here is a *dynamic* view (also called a *process*-related view) where mathematics can be understood as a science which mainly consists of problem-solving processes and discovery (Felbrich, Kaiser, and Schmotz 2012). Preschool teachers seem to support dynamic aspects of mathematics only to a limited extent (Benz 2012a).

Thiel (2010) found that preschool teachers who regarded mathematics as highly *relevant* for everyday life, also placed high emphasis on the *dynamic nature* of mathematics. In contrast, preschool teachers who regarded mathematics as less relevant, favored a schematic nature of mathematics. A similarly interrelated set of beliefs was found by Stipek et al. (2001) with primary teachers.

Another important dimension of mathematics-related beliefs are beliefs that express stereotypes about the ability to learn mathematics (Braeken and Blömeke 2016) including group-specific stereotypes towards students with special needs or second-language learners (Bertrand and Marsh 2015). When holding such beliefs, teachers might show different expectations towards children viewed as 'less able' resulting in a self-fulfilling prophecy (Rosenthal and Jacobson 1968).

Gender stereotypes are one of the categories of substantial concern because gender-specific differences in mathematics achievement have existed in many Western countries for a long time (Stoet and Geary 2013). Research revealed in this context that females often do worse only because they share the societal belief that women are less capable mathematically although there is no cognitive reason for such differences ('stereotype threat'; Spencer, Logel, and Davies 2016). Research suggests that teachers have a major impact on the formation of children's gender stereotypes (Tiedemann 2000). To our knowledge, data about prospective preschool teachers' beliefs in this respect is lacking.

A basic beliefs facet that has a more affective connotation and could therefore also be labeled an attitude is *enjoyment*. Motivational theory points out that if someone enjoys an activity, he or she is much more likely to implement it, and – even more important in the informal context of preschool – actively interested in creating opportunities where such activities can be carried out (Richardson 1996; Singh, Granville, and Dika 2002). German prospective and practicing preschool teachers' attitudes towards mathematics seem to be positive given that adjectives such as interesting were more often chosen than negative adjectives such as boring in a study by Benz (2012a). Only one fifth regarded mathematics as fascinating though.

Cognitive, educational and psychological determinants of prospective preschool teacher beliefs

Cognitive determinants

Knowledge and beliefs are supposed to be closely intertwined (Kelchtermans 2009). Only a few studies exist, though, that have tested prospective preschool teachers' knowledge and examined its relation to beliefs. One of the few studies available (Dunekacke et al. 2016)

showed significant positive correlations between prospective preschool teachers' mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK) on the one hand and beliefs about the relevance and the dynamic nature of mathematics on the other hand. Higher domain-specific knowledge seems to enable teachers to see the characteristics of mathematics in a better way.

Similar results were found by Blömeke (2012) with respect to primary teachers. She found in addition a negative relationship between MPCK and the belief that mathematics is a fixed ability including gender stereotypes but not between MCK and this belief. Higher MCK does not seem to be sufficient for the development of appropriate beliefs about how children acquire mathematics literacy.

Studies about the relation of general pedagogical knowledge (GPK) to mathematics-related beliefs of prospective teachers which could confirm or reject the domain-specificity of cognitive determinants are, to our knowledge, missing. The present study intends to close this research gap.

Educational determinants

Beliefs are shaped through experiences and formal education (McMullen 1997). In many countries, preschool teachers do not receive extensive training in mathematics (Copple 2004). Even at higher education institutions, most programs focus on general pedagogy (Early and Winton 2001). With respect to Germany, a recent study revealed that opportunities to learn (OTL) mathematics and mathematics pedagogy were offered to a lower degree than OTL in general pedagogy, both at vocational schools and at pedagogical colleges in Germany (Blömeke et al. 2017).

Specific research on the impact of OTL during preschool teacher education on beliefs is scarce. If one uses majors or degrees as rough approximations, it seems as if preschool teachers with higher education levels or with specialized early childhood training agreed more strongly with appropriate teaching and learning beliefs (McMullen 1998; Wang et al. 2008). It is important though to broaden this insufficient state of research by examining the relation of specific educational characteristics to prospective preschool teachers' beliefs. OTL in mathematics, mathematics pedagogy and general pedagogy were therefore included in the present study.

Psychological determinants

Since personality also determines individuals' responses to the environment (Musek 1999) and leads to consistent human behavior (John and Srivastava 1999), psychological determinants were studied as well. In contrast to pre-planned, formal and structured learning activities in primary schools, learning in preschools is less well-defined because it takes place in open and informal settings (Dunekacke, Jenßen, and Blömeke 2015a) where teachers have to identify their potential for fostering early mathematics literacy (Warfield 2001). Such working conditions require seeing the need of acting flexibly and of adapting to changing situations as well as being willing to do so which is called 'psychological flexibility' (Ben-Itzhak, Bluvstein, and Maor 2014).[1] Research revealed that psychological flexibility is positively related to job performance, daily well-being and lasting psychological health (Kashdan 2010).

The working conditions in preschool also require a willingness to reflect about and evaluate oneself. Grant, Franklin, and Langford (2002, p. 821) defined self-reflection as

'the inspection and evaluation of one's thoughts, feelings, and behavior'. Self-reflection has a significant positive relationship with self-consciousness and it is central to cognitive skills such as self-regulation (Silvia and Phillips 2011).

We are not aware of studies that examined the relation of flexibility and self-reflection to prospective preschool teachers' mathematics-related beliefs although the literature requires such personality traits for preschool teachers (NAEYC 2009).

Research questions and hypotheses

Three research questions with respect to prospective preschool teachers' beliefs and their determinants are examined in this study:

1. How are the different types of beliefs related to each other?

We hypothesize that prospective preschool teachers' mathematics-related beliefs form an interrelated set of beliefs that represents a coherent belief system (H1). The relevance of mathematics, the dynamic nature of mathematics and the enjoyment of mathematics would then be positively correlated whereas gender-stereotypes would be negatively correlated with these beliefs. A precondition would be that the four types of beliefs form separable constructs that tap into different dimensions of beliefs.

2. How pronounced are the different beliefs in prospective preschool teachers at different stages of their programs and at different institutions?

We hypothesize that preschool teachers at the end of teacher education have more favorable beliefs – in terms of believing more strongly in the relevance, dynamic nature and enjoyment of mathematics and less strongly in gender-stereotypes – than teachers at the beginning (indicating development or progress during teacher education) and that those studying at higher education institutions have more favorable beliefs than teachers at vocational schools (indicating higher educational quality through (self-)selection of students and/or more OTL) (H2).

3. To what extent do cognitive, educational and psychological characteristics of prospective preschool teachers determine their mathematics-related beliefs?

We hypothesize that teachers' knowledge and OTL are related to beliefs in a domain-specific way (H3). MCK and MPCK should be positively related to beliefs about the relevance, dynamic nature and enjoyment of mathematics but negatively to gender-stereotypes. Due to the lack of domain-specificity, GPK should not be related significantly to these beliefs at all. Prospective preschool teachers' OTL in mathematics and mathematics pedagogy should be positively related to their beliefs about the relevance, dynamic nature and enjoyment of mathematics. Gender-stereotypes are hypothesized to be significantly negatively related to OTL in mathematics pedagogy only. Due to the lack of domain-specificity we do not hypothesize significant relationships between OTL in general pedagogy and mathematics-related beliefs.

We hypothesize that specific preschool teachers' personality traits are significantly related to their mathematics-related beliefs (H4). Due to the generic nature of the personality traits we do not expect high correlations though. Given the lack of prior research we refrain from formulating more specific hypotheses.

Methods

Participants

The sample included 1851 prospective preschool teachers from 86 classes in 44 teacher education institutions in Germany. Classes had between 6 and 82 students ($M = 21$). The 44 institutions included 31 vocational schools with a total of 67 classes ($M_{\text{Stud/Class}} = 20$, Range = 6 to 46) and 13 pedagogical colleges with a total of 19 classes ($M_{\text{Stud/Class}} = 25$, Range = 6 to 82). 86% of the participants were female. 44% had a middle school degree as the highest educational degree whereas 56% had a high-school exit exam ('Abitur' or 'Fachhochschulreife'). The average math grade was 3.0 on a scale from 1 (best grade) to 6 (worst grade) with the pass-fail threshold set at 4.0.

Four groups were tested (see Table 1): prospective preschool teachers at the end and at the beginning of teacher education from institutions offering (post-)secondary education (vocational schools) or higher education (pedagogical colleges). Prospective preschool teachers in higher education were purposefully oversampled because otherwise the group would have been too small for scaling purposes.

The descriptive statistics of the four subgroups were in line with the demographics of the target population (see Table 2). The teachers in our sample who were at the end of preschool teacher education were two (vocational schools) or four (pedagogical colleges) years older than those who were at the beginning. Female teachers represented the majority in all four subgroups, and teachers' language background was almost always German. The biggest differences existed with respect to the two indicators of prior knowledge (school degree and number of years of mathematics in school) and the two indicators of socioeconomic background (mother's education and number of books at home). On each of the four indicators, participants from vocational schools were at a disadvantage compared with higher education students.

Measures

Prospective preschool teachers' beliefs

Beliefs about the Relevance of Mathematics (REL) were surveyed with six items from a scale well-established in teacher education research (e.g. Tatto et al. 2012) and developed by Grigutsch, Raatz, and Törner (1998). The scale which represents an applied view on how useful mathematics is was adjusted to the target population of this paper. Participants

Table 1. Sample size.

Type of institution	Vocational school	Pedagogical college	Overall
Program stage			
First year	594 (32%)	287 (15%)	881 (47%)
Last year	774 (42%)	196 (11%)	970 (53%)
Overall	1,368 (74%)	483 (26%)	1,851 (100%)

Table 2. Descriptive statistics of the sample by subgroup.

	First year vocational school	Last year vocational school	First year pedagogical college	Last year pedagogical college
Age in years (Range)	22 (17–53)	24 (18–54)	22 (18–47)	26 (19–53)
Gender (female)	85%	83%	90%	90%
German language background (always spoken at home)	88%	89%	83%	86%
No. of books at home (> 200)	23%	24%	41%	44%
Mother's education (at least a high-school degree)	17%	16%	32%	27%
Participant's own education (at least a high-school degree)	36%	44%	99%	99%
No. of years of mathematics in school (≤ 10)	47%	48%	2%	5%

were asked to rate the items on a six-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. A Confirmatory Factor Analysis (CFA) revealed good psychometric properties ($X^2_{(8)} = 58.6^*$; $CFI = .98$; $RMSEA = .06$). All items of the belief scales are documented in the Appendix together with factor loadings, standard errors and p-values.

Beliefs about the Dynamic Nature of Mathematics (DYN) were surveyed with four items from another scale developed by Grigutsch, Raatz, and Törner (1998) and well-established in teacher education research (Tatto et al. 2012). The scale represents a process-oriented view on mathematics and was adjusted to the purpose of this paper. Participants were asked to rate the items on a six-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The model fit well to the data ($X^2_{(2)} = 1.9$, $p = 0.39$; $CFI = 1.00$; $RMSEA = .00$).

Five items assessed Beliefs about Gender Stereotypes regarding mathematics (GENDER). The scale was an extension from items already applied elsewhere (Tatto et al. 2012). Participants had to rate the items on a six-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The model fit well to the data ($X^2_{(4)} = 42.2^*$; $CFI = .99$; $RMSEA = .07$).

Beliefs about the Enjoyment of Mathematics (JOY) were surveyed with five items extending a set of items already applied elsewhere (Tatto et al. 2012). Participants had to rate these on a 6-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The model fit well to the data ($X^2_{(4)} = 32.3^*$; $CFI = .99$; $RMSEA = .06$).

Cognitive, educational and psychological predictors

24 dichotomously coded items assessed MCK. Content validity was confirmed by expert validation (Jenßen, Dunekacke, and Blömeke 2015). Open responses were required for 14 items, whereas 10 were multiple-choice items. Scale scores were created by applying a two-parameter logistic model based on item-response theory (2-PL IRT). Person parameters were transformed to a mean of 50 and a standard deviation of 10 test points (see Table 3). Scale reliability was good ($P\gamma = .88$; Raykov, Dimitrov, and Asparouhov 2010).

28 dichotomously coded items assessed MPCK (Dunekacke, Jenßen, and Blömeke 2015b). Open responses were required by five items, whereas 23 were multiple-choice or bundled items. Scores were created by applying a 2-PL IRT model. Score reliability was good ($P\gamma = .87$).

18 dichotomously coded items assessed GPK (Blömeke et al. 2015). Open responses were required by three items, whereas 15 were multiple-choice or bundled items. Scores

Table 3. Descriptive statistics of the predictors.

Variable	Mean	Minimum	Maximum
MCK	50.00	20.1	78.7
MPCK	50.00	14.5	74.1
GPK	50.00	19.9	75.7
OTL in mathematics	2.04	1.0	4.0
OTL in mathematics pedagogy	2.13	1.0	4.0
OTL in general pedagogy	3.06	1.0	4.0
Flexibility	3.35	1.0	6.0
Self-reflection	5.51	3.2	6.0

Note. MCK = mathematics content knowledge, MPCK = mathematics pedagogical content knowledge, GPK = general pedagogical knowledge, OTL = opportunities to learn.

were created by applying a 2-PL IRT model. Reliability was sufficient ($P\gamma = .68$). Good psychometric properties of all three knowledge scales could be confirmed based on a broad range of validity criteria (Blömeke et al. 2017).

Four items surveyed the coverage of OTL in mathematics. The items had to be rated on four-point Likert scales (1 = not at all, 4 = intensely). For descriptive statistics see Table 3. The reliability and model fit of the OTL in mathematics scale were good: $\alpha = .83$; $X^2_{(2)} = 2.85$, $p = .24$; CFI = 1.00; RMSEA = .02.

Seven items covered the extent to which prospective preschool teachers had had OTL in mathematics pedagogy. Scale reliability was very good and model fit was satisfactory: $\alpha = .92$; $X^2_{(19)} = 151.00^*$; CFI = 1.00; RMSEA = .06.

Four items surveyed the coverage of OTL in general pedagogy. The reliability was just satisfactory ($\alpha = .75$), but the model fit was very good: $X^2_{(5)} = 12.79$, $p = .03$; CFI = 1.00; RMSEA = .03. Good psychometric properties of all three OTL scales could be confirmed based on a broad range of validity criteria (Blömeke et al. 2017).

An established scale that covered the conative understanding of Flexibility applied in the present study did to our knowledge not exist at the beginning of our study (Ben-Itzhak, Bluvstein, and Maor 2014). Based on the state-of-research, five items were therefore developed that surveyed the intended conceptualization. Participants were asked to rate the items on six-point Likert scales ranging from 'strongly disagree' to 'strongly agree'. For descriptive statistics see Table 3. A CFA revealed good psychometric properties ($X^2_{(5)} = 42.4^*$; *CFI* = .97; *RMSEA* = .06). All items of the two personality scales are documented in the appendix.

Also in the case of Self-reflection an established scale that covered the understanding of self-reflection applied in the present study did not exist. Five items were developed that surveyed the need for and engagement in self-reflection (Grant, Franklin, and Langford 2002). A CFA revealed that the model fit well to the data ($X^2_{(5)} = 23.7^*$; *CFI* = .98; *RMSEA* = .05).

Data analysis

To test the hypotheses a series of CFA and structural equation models was applied. Missing values were included in a model-based iterative process by applying the full-information-maximum-likelihood (FIML) method, which uses all information available and is least prone to bias (Lüdtke et al. 2007). The nested structure of the data was taken into account by computing standard errors with a sandwich estimator that took the cluster sampling and unequal probability of selection into account as it is implemented in

Mplus version 7.3 (Muthén and Muthén 2014). Model fit was evaluated with absolute and relative goodness-of-fit statistics (Hu and Bentler 1999). Comparative fit index (CFI) estimates > .95 indicate a very good fit, and estimates > .90 a good model fit. Root mean square error of approximation (RMSEA) estimates < .05 indicate a very good fit, and estimates < .08 a good model fit.

Results

Correlation and level of mathematics-related beliefs (H1, H2)

The four types of beliefs about the relevance, nature and enjoyment of mathematics as well as about gender-stereotypes regarding mathematics formed empirically separable constructs that tapped into different dimensions of beliefs. Technically speaking this means that a four-dimensional model fit better to the data than a one-dimensional model that assumed only one underlying trait (see Table 4).

The hypothesized interrelated structure of prospective preschool teachers' beliefs was supported by the data (H1). The positive correlations between the beliefs that mathematics is relevant, of dynamic nature and enjoyable were rather strong (see Table 5). The negative correlation between these three beliefs and gender stereotypes was substantially lower but still significant.

Preschool teachers at the end of teacher education believed more strongly in the relevance, dynamic nature and the enjoyment of mathematics than those at the beginning (H2). The differences were substantial at both types of institutions but larger at pedagogical colleges than at vocational schools (see Table 6). The difference was largest with respect to the relevance of mathematics. In contrast to H2, prospective preschool teachers' gender stereotypes did not differ significantly between the beginning and the end of teacher education.

As hypothesized, preschool teachers at pedagogical colleges believed more strongly in the relevance, dynamic nature and the enjoyment of mathematics than those at vocational schools (see Table 6). The differences were less pronounced but already significant at the beginning of teacher education. At the end of teacher education, the differences were substantial. The difference was again largest with respect to the relevance of mathematics. In contrast to our hypothesis, neither at the beginning nor at the end of teacher education did prospective preschool teachers' gender stereotypes differ significantly.

Effects of cognition, education and personality (H3, H4)

As hypothesized (H3), prospective preschool teachers with higher MCK hold significantly stronger beliefs about the relevance, dynamic nature and enjoyment of mathematics, and they expressed significantly less pronounced gender-stereotypes than teachers with less

Table 4. Fit of four- and one-dimensional belief models.

	Chi-Square	*df*	*CFI*	*RMSEA*
Four dimensions	710.4[a]	161	.96	.04
One dimension	5,487.6[a]	167	.61	.13

Note. df = degrees of freedom, CFI = comparative fit index, RMSEA = root mean square error of approximation.
[a]$p < .01$.

Table 5. Correlation matrix of the four belief scales (latent correlations, standard error).

	Relevance	Dynamic Nature	Gender Stereotypes
Dynamic Nature	0.66 (0.02)[a]		
Gender Stereotypes	−0.19 (0.03)[a]	−0.15 (0.04)[a]	
Enjoyment	0.59 (0.03)[a]	0.52 (0.03)[a]	−0.20 (0.03)[a]

[a]$p < .01$.

Table 6. Descriptive statistics for prospective preschool teachers' beliefs by subgroup.

Beliefs	Start Vocational School	End Vocational School	Start College	End College
Relevance	−0.77 (0.09)	−0.47 (0.09)	−0.50 (0.12)	0.00 (0.00)
Dynamic Nature	−0.55 (0.12)	−0.35 (0.13)	−0.33 (0.15)	0.00 (0.00)
Gender Stereotypes	0.24 (0.13)	0.22 (0.12)	0.14 (0.14)	0.00 (0.00)
Enjoyment	−0.53 (0.12)	−0.34 (0.12)	−0.37 (0.14)	0.00 (0.00)

MCK (see Table 7). Similarly with respect to MPCK, the data supported the hypothesized significant positive relations to beliefs about the relevance, dynamic nature and enjoyment of mathematics. All effects were of moderate strength. A significant relationship between GPK and any of the mathematics-related beliefs did not exist which supports the hypothesized domain-specificity of the relation between knowledge and beliefs. In contrast to our hypothesis, a significant negative relationship of MPCK to gender-stereotypes did not exist.

The domain-specificity of relations between OTL and prospective preschool teachers' beliefs was also largely supported by the data (H3). As hypothesized, OTL in general pedagogy were not significantly related to any type of mathematics-related belief (see Table 7). In contrast, preschool teachers who had had more OTL in mathematics pedagogy during teacher education hold significantly stronger beliefs about the relevance, dynamic nature and the enjoyment of mathematics than teachers with fewer OTL and they expressed significantly less pronounced gender-stereotypes. The effects OTL in mathematics pedagogy were more pronounced than those of OTL in mathematics although these were also significantly positively related to beliefs about the relevance, dynamic nature and the enjoyment of mathematics. However, the strength of these relations were neglectable. A significant relation between OTL in mathematics and gender-stereotypes did not exist, either.

Finally, as hypothesized (H4), prospective preschool teachers who were more flexible believed more strongly in the relevance and dynamic nature of mathematics, disposed of less strongly pronounced gender-stereotypes and they enjoyed mathematics more

Table 7. Effects of cognitive, educational and psychological determinants on prospective preschool teachers' beliefs (standardized estimates).

	Knowledge			OTL in			Personality	
Beliefs	MCK	MPCK	GPK	Mathematics	Math pedagogy	General pedagogy	Flexibility	Self-reflection
REL	.15 (.03)[a]	.20 (.03)[a]	.05 (.03)	.08 (.03)[a]	.24 (.03)[a]	−.03 (.03)	−.16 (.03)[a]	.21 (.02)[a]
DYN	.15 (.03)[a]	.14 (.03)[a]	.06 (.03)	.07 (.03)[a]	.18 (.04)[a]	−.01 (.03)	−.12 (.03)[a]	.15 (.03)[a]
GEN	−.10 (.03)[a]	−.06 (.03)	−.04 (.03)	.01 (.04)	−.08 (.03)[a]	.01 (.03)	.15 (.02)[a]	−.09 (.02)[a]
JOY	.28 (.03)[a]	.11 (.03)[a]	−.01 (.03)	.09 (.03)[a]	.19 (.04)[a]	−.03 (.03)	−.19 (.03)[a]	.08 (.02)[a]

Note. MCK = mathematics content knowledge, MPCK = mathematics pedagogical content knowledge, GPK = general pedagogical knowledge; OTL = opportunities to learn; REL = relevance, DYN = dynamic nature, JOY = enjoyment of mathematics, GEN = gender-stereotypes. Higher values on the flexibility scale indicate lower flexibility (see Appendix).
[a]$p < .05$.

Table 8. Full model of belief determinants (standardized estimates).

	Knowledge		OTL in		Personality	
	MCK	MPCK	Mathematics	Math pedagogy	Flexibility	Self-reflection
REL	.15 (.03)[a]	.14 (.03)[a]	.08 (.03)[a]	.18 (.03)[a]	−.10 (.02)[a]	.16 (.02)[a]
DYN	.15 (.03)[a]	.10 (.03)[a]	.07 (.03)[a]	.14 (.03)[a]	−.07 (.03)[a]	.11 (.03)[a]
GEN	−.09 (.03)[a]	−.04 (.03)	.01 (.03)	−.05 (.03)	.13 (.02)[a]	−.07 (.03)[a]
JOY	.27 (.03)[a]	.04 (.03)	.09 (.03)[a]	.15 (.03)[a]	−.12 (.02)[a]	.05 (.02)[a]

[a]$p < .05$.

than prospective preschool teachers with lower flexibility scores (see Table 7). Similarly, teachers who revealed higher self-reflection believed more strongly in the relevance and dynamic nature of mathematics, disposed of less strongly pronounced gender-stereotypes and enjoyed mathematics more. In contrast to our expectation of only small effect sizes due to the generic nature of the traits, the size of the correlations were similar to effects of other predictors.

Incremental effects of cognition, education and personality

The final model included all predictors that had revealed effects on the beliefs scales. GPK and OTL in general pedagogy were left out because, as hypothesized, they were not significantly related to mathematics-specific beliefs of prospective preschool teachers.

If one looks first at the effect sizes of each predictor in the full model compared to the models that included the different types of predictors separately, the data revealed that the relations to prospective preschool teachers' beliefs were weakened but still significant in the case of MPCK, OTL in mathematics pedagogy and the two personality characteristics (see Table 8). The strength of the relations of MCK and OTL in mathematics to beliefs remained the same.

Each predictor had a significant incremental impact on at least two types of beliefs even if the other predictors were controlled for. The data revealed similar patterns for prospective preschool teachers' beliefs about the relevance, dynamic nature and the enjoyment of mathematics (see Table 8). In all three cases, the most important knowledge and OTL predictors were MCK and OTL in mathematics pedagogy. MPCK and OTL in mathematics seemed to have lower effects. In addition, self-reflection had the most important incremental effects on the two cognitively connoted beliefs whereas flexibility had the most important incremental effect on the affective ones. Gender stereotypes were generally only weakly or not at all related to the predictors; flexibility was the predictor with the largest effect in this case.

Discussion

Four types of beliefs about the relevance, dynamic nature and enjoyment of mathematics as well as about gender-stereotypes regarding mathematics were examined in this paper with a heterogeneous sample of prospective preschool teachers from different types of teacher education programs and at different stages of their training. These beliefs tapped into different dimensions but were correlated to each other. Such a structure points to a well-connected coherent belief *system* as Schommer-Aikins (2004) pointed out.

Because of its coherence such a system is typically difficult to change. Nevertheless the notion of 'development' during teacher education was supported by the data. Preschool teachers at the end of teacher education and those studying at pedagogical colleges believed more strongly in the relevance and dynamic nature of mathematics and enjoyed mathematics more strongly than preschool teachers at the beginning of their training and at vocational schools.

These differences may result from differences in entrance requirements and OTL because significant relationships were found both with prospective preschool teachers' knowledge and their OTL to beliefs. Domain-specificity may be the key here which would extend previous primary and secondary teacher research (Bromme 2005) to preschool teachers. The data supported in particular the relevance of MCK and OTL in mathematics pedagogy.

Gender-stereotypes represented in many respects an outlier. Correlations with the other types of beliefs were low, 'development' during teacher education was not supported by the data, and gender-stereotypes were less strongly related to knowledge or OTL. These results indicate that stereotypes may be very difficult to change.

Limitations of the study

Causal inferences cannot be drawn from this study because of its cross-sectional design. In particular, inferences about 'development' over the course of preschool teacher education need to be made with care. Furthermore, whereas most measures applied have previously been validated or represent adapted versions of scales well-rooted in the teacher literature, the personality measures were of more novel nature. The robustness of our findings would be strengthened if they were examined with other samples, in particular from other countries, and with other measures of the same constructs.

Conclusions and further research

Based on our results, it seems to be important not only to include pedagogical content knowledge or corresponding OTL in studies of preschool teachers but also pure content knowledge and corresponding OTL although its relevance is widely controversial. Accuracy in research requires evidence in this respect though, which necessarily means to include MCK and OTL in mathematics.

The differences in prediction through MCK and OTL in mathematics pedagogy may support the hesitations against delivery of pure content knowledge in preschool teacher education. Given the lack of 'development', the mathematics content knowledge level included in our study corresponds to high school mathematics only though. This seems in any case to be necessary (see its predictive power) and corresponds to other studies (Dunekacke et al. 2016) – but this level may then also be sufficient because OTL in mathematics were not significantly related to beliefs. This hypothesis needs to be tested in further research. In contrast, OTL in mathematics pedagogy were particularly relevant, and they seem to have the potential to change the whole belief systems of prospective preschool teachers. These results support previous results that it is less relevant *where* teacher education takes place than what a program includes (Blömeke et al. 2017; Vu, Han, and Buell 2015).

Regarding gender stereotypes of prospective preschool teachers, flexibility was most strongly related to them which may point to the personality-related nature of this belief. Generally, it was surprising to note the size of the correlations between personality traits and prospective preschool teachers' mathematics-related beliefs. Despite their generic nature separate and incremental effects existed with effect sizes that corresponded to the domain-specific predictors.

Important follow-up questions to our study target the role of general cognitive ability. Controlling for it may change the picture with respect to beliefs with a cognitive connotation. In addition, the question remains to what extent beliefs have incremental predictive validity for teacher behavior compared to knowledge. It would be important to include both facets within one study. Currently, a gap between research on preschool teachers' knowledge and beliefs exists.

Note

1. The conative understanding of flexibility used here differs from a cognitive understanding that includes performance aspects (e.g., Elen et al. 2011).

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Appendix

Table A1. Items (translated), standardized factor loadings, standard errors (SE) and p-values.

Relevance of mathematics (REL)	Loading	SE	p
Mathematics helps solving everyday problems and tasks.	0.80	0.01	0.00
Everyday situations offer the possibility to make practical experiences with mathematics.	0.77	0.01	0.00
Mathematics helps to understand everyday tasks in a better way.	0.73	0.02	0.00
Mathematics is an important part of our culture.	0.67	0.02	0.00
Many aspects of mathematics are of practical relevance.	0.66	0.02	0.00
Mathematical concepts are of low practical relevance for everyday tasks (R).	0.55	0.03	0.00
Dynamic nature of mathematics (DYN)			
Mathematics means creativity and new ideas.	0.78	0.02	0.00
Mathematical activity is inventing and reinventing mathematics.	0.75	0.02	0.00
In mathematics many things can be discovered and tried out by oneself.	0.71	0.02	0.00
Mathematics is an activity involving thinking about problems and gaining insight.	0.63	0.02	0.00
Gender stereotypes regarding mathematics (GENDER)			
Girls need more support in mathematics than boys.	0.92	0.01	0.00
Boys are more competent in mathematics than girls.	0.82	0.01	0.00
Boys have a mathematical mind.	0.78	0.02	0.00
Girls and boys are able to solve mathematical problems to the same extent (R).	0.74	0.02	0.00
Mathematics is the favorite subject of boys rather than girls.	0.58	0.02	0.00
Enjoyment of mathematics (JOY)			
Mathematics is enjoyable.	0.93	0.01	0.00
It is hard to enjoy mathematics (R).	0.81	0.02	0.00
Mathematics is boring (R).	0.77	0.02	0.00
Mathematics leads to enjoyable experiences.	0.76	0.02	0.00
Mathematics offers the possibility to enjoy discoveries.	0.70	0.02	0.00

Note. (R) = recoded.

Table A2. Personality characteristics: items (translated), standardized factor loadings, standard errors (SE) and p-values.

Flexibility	Loading	SE	p
It is desirable that everything at the job functions as usual.	0.74	0.02	0.00
It is important not to deviate from one's daily routines.	0.61	0.03	0.00
It is desirable that one can plan a working day beforehand.	0.56	0.02	0.00
Job requirements should be limited to clearly defined tasks.	0.47	0.03	0.00
One should be skeptical towards new situations.	0.39	0.03	0.00
SELF-REFLECTION			
It is important to pay attention to one's own behavior also in challenging situations with preschool children.	0.67	0.03	0.00
It is important to reflect about how to improve one's own work with preschool children.	0.63	0.03	0.00
It is necessary to spend time on reflections about one's own work with preschool children.	0.59	0.03	0.00
If one knows oneself well, one is able to address preschool children's needs in a better way.	0.50	0.03	0.00
One should reflect about criticism targeting the work in one's own preschool group.	0.46	0.03	0.00

Table A3. Fit of models that predict prospective preschool teachers beliefs.

Beliefs on	X^2	*df*	*CFI*	*RMSEA*
Knowledge	888.0[a]	209	.95	.04
OTL	787.4[a]	209	.96	.04
Personality characteristics	803.1[a]	193	.96	.04
Full model	960.1[a]	257	.95	.04

[a]$p < .01$.