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ARTICLE

Preschool teachers' pedagogical content knowledge predicts willingness to scaffold early science learning

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Abstract

Background: The importance of diagnostic and scaffolding activities for early science learning has been shown consistently. However, preschool teachers scarcely engage in them. We developed an instrument to assess preschool teachers' willingness to engage in diagnostic and scaffolding activities in science learning situations and examined its relation with teachers' knowledge, beliefs and practice.

Aims: We validate an instrument to assess willingness to engage in scaffolding and diagnostic activities and study the interplay between willingness, learning beliefs, content knowledge (CK) and pedagogical content knowledge (PCK) in the context of science learning, particularly block play.

Sample(s): A total of $N = 151$ preschool teachers from 41 kindergartens in Germany participated in our study.

Methods: Preschool teachers completed a questionnaire, which took approximately 1 hour of time. We drew a subsample of $N = 73$ teachers and observed their practice during a 30 min block play episode.

Results: With our instrument, we were able to distinguish between preschool teachers' willingness to diagnose and to scaffold. Preschool teachers' co-constructivist beliefs and PCK predicted willingness to engage in diagnosing, PCK also predicted willingness to engage in scaffolding. Associations between learning beliefs and practice were inconsistent.

Conclusions: Our study highlights aspects of the association between preschool teachers' PCK and their willingness

to engage in diagnosing and scaffolding. However, we found inconsistencies between preschool teachers' beliefs and practice, which call for further clarification.

KEYWORDS

block play, preschool teachers, scaffolding, science teaching, teacher beliefs, teacher knowledge, willingness

THEORY

Interest in early science learning has increased during the last years because preschool children's knowledge is predictive for later achievement and school success (Morgan et al., 2016; Trundle & Saçkes, 2015). There is growing consensus that science education should start early (Anders & Rossbach, 2015; Dunekacke et al., 2021; Möhring et al., 2021) and that early science should include inquiry-based and child-centred activities (Gropen et al., 2017). Appropriately structured learning situations are needed to support children's learning (Hadzigeorgiou, 2002). Thus, curricular guidelines call for promoting children's pre-academic skills (ECEC/OECD, Anders, 2015). To foster children's learning, preschool teachers need to have content knowledge (CK), which refers to teachers' understanding of the subject matters' concepts, principles and theories and pedagogical content knowledge (PCK, cf. Shulman, 1987), which refers to knowledge of effective teaching strategies such as scaffolding as well as techniques for assessing children's learning (Shulman, 1987). However, preschool teachers face problems supporting young children's learning, especially in the STEM fields, as they often feel ill-prepared for the task (Spektor-Levy et al., 2013).

Despite multiple empirical findings confirming the importance of science education (McCray & Chen, 2012; Möhring et al., 2021; Zhang & Lin, 2017), some preschool teachers still view science learning as inappropriate for the early childhood years (Park et al., 2017). The promotion of process skills (e.g. hypothesizing) is usually neglected in early childhood education (LaParo et al., 2004). Traditional approaches focus on children's spontaneous activities that should be the root of kindergarten teaching and favour socio-pedagogic approaches (ECEC/OECD, Anders, 2015).

However, it remains unclear whether teachers' beliefs about early science learning transfer into a willingness to engage in science teaching (Buehl & Beck, 2015) and how their interplay affects preschool teachers' practice. Thus, we investigated beliefs, willingness to engage in early science, CK and PCK in a sample of $N = 151$ German preschool teachers and analysed their practice $N = 73$ interactions. In Germany, children typically attend kindergarten from 3 to 6 years of age. With our study, we focus on a clarification of the relationship between teachers' dispositions and practice.

Willingness to engage in learning situations

Models of teachers' professional competence (Baumert & Kunter, 2006; Blömeke et al., 2015; Gess-Newsome, 2015) assume that teachers' performance in learning situations is determined by motivational-affective states (e.g. self-efficacy), knowledge facets (e.g. CK, PCK) and attitudes (e.g. learning beliefs). However, various studies have shown that these dispositions do not always influence teachers' practice (Akerson et al., 2010; Blömeke, 2012; Liu, 2011; Wilcox-Herzog, 2002). A promising approach to explain the lack of correlation between teachers' dispositions and their practice may be the theory of planned behaviour, which identifies willingness to bridge the gap between beliefs and practice (Fishbein & Ajzen, 2010; Fröhlich-Gildhoff et al., 2011). In our case, willingness represents the inner readiness to teach science although it is not mandatory (Heuckmann, 2020).

The explanatory power of willingness has been widely demonstrated in different contexts such as alcohol and drug use (Armitage et al., 2014), healthy nutrition (Zoellner et al., 2013), physical

activity (Darker et al., 2010) or workplace health (Sheeran & Silverman, 2003). However, according to Cooper et al. (2016), the predictive power of willingness for teacher behaviour is less apparent than in other contexts because in teaching, there are many influencing factors (beliefs, CK and PCK) to consider (Chan & Lay, 2021; Lee et al., 2010; van Aalderen-Smeets et al., 2012). In the context of early science learning, empirical research and instruments to assess willingness are still sparse. Thus, we developed an instrument to assess willingness in the context of early science learning and to analyse its relationships with preschool teachers' knowledge about early science and their learning beliefs.

Preschool teachers' knowledge about science teaching

Studies suggest that preschool teachers' knowledge has an impact on the quality and frequency of science teaching and children's learning (Kallery & Psillos, 2001; McCray & Chen, 2012). Therefore, knowledge is considered an integral part of professional competence models and thus instructional quality (Baumert & Kunter, 2006; Fröhlich-Gildhoff et al., 2011). Studies demonstrate a considerable variance in preschool teachers' science-specific CK, PCK and their teaching (Barenthien et al., 2020; Pianta, La Paro, & Hamre, 2008; Pianta, Mashburn, et al., 2008).

Research indicates that preschool teachers have low science CK (Garbett, 2003; Kallery & Psillos, 2001; Yıldırım, 2021). CK has shown to be important for recognizing learning opportunities in preschool, which are usually embedded in play situations (Dunekacke et al., 2015; Oppermann et al., 2016; Samuelsson & Carlsson, 2008). Hence, preschool teachers need to recognize these learning situations by carefully observing the situations and applying diagnostic strategies.

Pedagogical content knowledge is conceptualized as the subject-specific learning support provided by the teacher (Gess-Newsome, 2015; Leuchter et al., 2020) and is an important predictor for instructional quality and student's learning gains (Kunter, 2013; McCray & Chen, 2012). Diagnostic activities are regarded as a basis for fostering children's development and for the application of adequate scaffolding techniques (Leuchter et al., 2020; Van de Pol et al., 2010), and thus are important for preschool educational programs (Schmidt & Liebers, 2017). However, preschool teachers often lack PCK (Barenthien et al., 2020) to promote the development of science-specific procedural skills in kindergarten children and to foster their understanding (Piasta et al., 2014; Roth, 2014).

The benefits of scaffolding for children's learning have been shown consistently (Hong & Diamond, 2012; Leuchter & Saalbach, 2014; Weisberg et al., 2016). Studies report that children supported by scaffolding are more likely to develop science competences (French, 2004; Klahr et al., 2011; Samarapungavan et al., 2008). However, preschool teachers seem to face difficulties in supporting children's knowledge as a part of STEM even during everyday activities (Spektor-Levy et al., 2013). Moreover, scaffolding techniques requiring high PCK were observed less than non-challenging teacher support (Leuchter & Saalbach, 2014).

In sum, studies suggest that preschool teachers' use of diagnostic and scaffolding activities in everyday situations and in science teaching is rare (Cabell et al., 2013; Leuchter & Saalbach, 2014; von Suchodoletz et al., 2014). Studies demonstrate that preschool teachers are in favour of organizing play over supporting learning through diagnosing and scaffolding (Leuchter & Saalbach, 2014; Sylva et al., 2007). Drawing on the abovementioned findings, we can assume that a considerable amount of variance in the use of diagnostic and scaffolding techniques might be ascribed to preschool teachers' differences in CK (Barenthien et al., 2020) and PCK (Pianta, La Paro, & Hamre, 2008; Pianta, Mashburn, et al., 2008).

Teachers' beliefs about science teaching

Beliefs about learning and teaching are an integral part of teachers' competencies (Leuchter et al., 2020) and influence professional practice (Richardson, 2003; Wilkins, 2008). Some authors have argued that

teachers' beliefs act as amplifiers and filters for teachers' professional practice (Buehl & Beck, 2015). Co-constructivist beliefs stress the importance of a dialogic and interactive process between teacher and child, in which knowledge is mutually constructed (Chi & Menekse, 2015). These beliefs encompass the view that children restructure their prior knowledge to generate coherent explanations when supported by the teacher (Schmidt & Smidt, 2021).

However, hands-on activities are frequently mistaken as a form of co-constructivist learning (Haefner & Zembal-Saul, 2004). Constructivist beliefs are often contrasted with instructivist beliefs, which stress a teacher-centred view and conceptualize teaching as a unidirectional process (Schmidt & Smidt, 2021). Teachers who hold instructivist beliefs think that an informed adult transmits knowledge to children (Leuchter et al., 2020). Research indicates that this view is incompatible with science education that fosters children's understanding of science phenomena (Saçkes et al., 2011). Autonomy beliefs stem from a situation-oriented approach, which is particularly prominent in Germany (ECEC/OECD, Anders, 2015). These beliefs emphasize children's socio-emotional development, whereas the development of early academic skills is less valued (Merkel, 2013).

Leuchter et al. (2020) examined a Swiss sample of preschool teachers and differentiated between highly co-constructivist, low co-constructivist and instructivist beliefs, with the latter being the largest group. They found that teachers with high constructivist beliefs ranked highest in PCK. Rank (2009) showed that most German preschool teachers engage in instructivist forms of learning. An international study has provided evidence that teachers with low CK and PCK tend to view learning from a transmissive point of view (Blömeke, 2012). However, a recent German study suggests that instructivist beliefs are less pronounced than previously thought compared to co-constructivist or autonomy beliefs (Schmidt & Smidt, 2021). A Greek study implies that preschool teachers' beliefs towards teaching science are generally positive (Bourotzoglou et al., 2016), however, teachers were unwilling to spend time creating science learning materials and did not consider children's experimenting as an adequate way of learning.

The expectation that teacher beliefs directly transfer into practice is not met by empirical studies (Buehl & Beck, 2015). Some studies have shown weak associations between teachers' beliefs and self-reported teaching practice (Mohamed & Al-Qaryouti, 2016; Stipek & Byler, 1997; Waters-Adams, 2006). Moreover, contextual conditions have shown to play a major role. Although preschool teachers can hold co-constructivist beliefs, they might not act accordingly, if their colleagues do not support co-constructivist beliefs or if the classroom requires a lot of organizing and structuring (Hur et al., 2016; Kaufman & Moss, 2010; Stofflett & Stoddart, 1994).

Despite the small correlations reported in other studies, some authors advocate for the importance of teachers' beliefs for teaching practice (Maxwell et al., 2001). Studies with preschool and elementary school teachers have reported medium to high correlations between beliefs and observed instructional practice (Perren et al., 2017; Quance et al., 2008; Slot et al., 2015). In a Taiwanese study, Tsai (2006) found that teachers holding instructivist beliefs focused predominantly on student's test scores and viewed student's roles as more passive. Moreover, classroom quality was higher for preschool teachers, who held child-centred beliefs (Pianta et al., 2005). Furthermore, preschool teachers who held developmentally appropriate beliefs, such as co-constructivist beliefs, engaged more in problem-based learning than teachers with instructivist beliefs (McMullen et al., 2006). Yet, when considering teachers from all grade levels, the association between practice and beliefs seems to be weaker for co-constructivist than for instructivist approaches (Mansour, 2013).

Empirical evidence points towards a complex association between beliefs and practice. Yet, teachers' willingness to engage in a specific practice could bridge the gap between their beliefs and enacted practice. As research has shown that preschool teachers tend to prioritize play-based activities (Leuchter & Saalbach, 2014; Sylva et al., 2007), we focus on the context of block play as an important aspect of science education (Weber et al., 2020).

Block play

Studies on supporting knowledge through block play have focused on parent–child (Ferrara et al., 2011) or researcher–child interactions (Weber et al., 2020), while studies on teacher–child interactions during block play remain sparse. In block play, one of the central aspects is stability. To estimate the stability of an asymmetrical block construction, knowledge about mass must be applied (CK). In this context, PCK can be understood as identifying the potential of block play for learning (e.g. mathematics, statics, language). We chose block play as an everyday kindergarten activity to assess preschool teachers' CK and PCK as well as their practice.

Drawing from the abovementioned findings, we aim to measure and test factorial validity of a newly designed test instrument to assess willingness to engage in scaffolding and diagnostic activities and study the interplay between willingness, learning beliefs, CK and PCK.

Research questions

1. Does the instrument for assessing willingness differentiate validly between Diagnosis, Scaffolding and Inactivity?
2. How are preschool teachers' CK, PCK, learning beliefs, willingness and their practice (scaffolding) related?
3. Which variables showing significant bivariate correlations bear incremental validity in the prediction of willingness to engage in scaffolding, diagnosis and inactivity?

METHODS

The research was conducted from January to July 2022 in $N = 41$ German kindergartens. The sample consisted of $N = 151$ preschool teachers. $N = 85$ preschool teachers provided demographical data ($M_{age} = 35.76$; $SD_{age} = 13.18$; 87% female; with a professional experience of $M_{exp} = 12.85$; $SD_{exp} = 11.59$ years), in which 83% had passed a vocational training programme, 5% held a university degree and 12% had any other professional qualification. All participants were informed about the goal of the study and consented to participation. The study was approved by the local Ethics Committee.

Instruments

Preschool teachers completed the 1-hour questionnaire on a tablet computer. The questionnaire was administered in German and the items were translated for this article. All reported scales were part of the questionnaire but were administered within different sections.

Willingness

We designed vignettes (VIG) that each displayed a playful science learning opportunity, which offered the chance to apply diagnostic and scaffolding techniques. In expert discussions, five science learning opportunities in preschool were identified which could be presented textually and graphically (VIG 1: stability and weight, VIG 2: magnetism, VIG 3: materials and their characteristics, VIG 4: stability in block play, VIG 5: marble run (inclined plane)). Research has shown that German preschool teachers favour autonomy beliefs (ECEC/OECD, Anders, 2015) and that diagnosing and scaffolding to support learning is not the focus of preschool teachers (Leuchter & Saalbach, 2014; Sylva et al., 2007). On this

basis, we distinguished three willingness dimensions: willingness to engage in diagnostic (DIA), scaffolding (SCAF) and inactivity (INA).

We conducted two pilot studies to test factorial validity of our self-developed instruments (PCK, willingness). In a first pilot study with 35 preschool teachers, a maximum-likelihood exploratory factor analysis was tested for one-dimensionality of PCK. The one-factor solution yielded a good fit, $\chi^2(35) = 33.69$, $p = .531$. However, our vignette-based approach had to be adapted considering the mediocre reliability of the items. After repeated expert discussions, we changed the item's wording to clarify its meaning. In a second pilot study with 40 preschool teachers ($M_{age} = 40.10$, $SD_{age} = 12.10$), we again tested the reliability and dimensionality of willingness. Reliability for willingness was good ($a_{DIA} = .93$, $a_{SCAF} = .82$, $a_{INA} = .82$). The empirical BIC reached a minimum with three factors.

Before presenting this part of the questionnaire, we gave a brief introductory text which informed teachers that we wanted to explore their willingness to provide learning support in five typical preschool science activities. Each of the five vignettes consisted of a drawing, a short introductory text describing the situation and six items which the participants had to rate on a 4-point Likert scale (1 = *do not agree at all*, 4 = *totally agree*; see Figure 1). Two items served as indicators for the diagnostic component, DIA; e.g. *I would observe attentively what the children are doing*, $a = .97$, ($CI_{95\%} = [.96; .97]$). Two items per vignette served as indicators for the scaffolding component, SCAF, e.g. *I would have a conversation with the children about what they are doing right now*, $a = .85$ ($CI_{95\%} = [.82; .89]$). Two items served as indicators for inactivity (INA; e.g. *I would leave the children on their own*, $a = .93$ ($CI_{95\%} = [.91; .94]$)). The items across all five vignettes were aggregated to a sum score.

Pedagogical content knowledge

Pedagogical content knowledge items (Table 1) were designed with experts by focusing on content-related and process-oriented aspects that can be applied in block play with children aged three to six, such as mathematics or hypothesizing. PCK in block play was assessed by 10 items rated on a 4-point Likert scale (1 = *do not agree at all* and 4 = *totally agree*). The participants rated the appropriateness of different possibilities to support children's block play (see Table 1). We computed a sum score, ranging from 0 to 40. Internal consistency was $\alpha = .85$, ($CI_{95\%} = [.80; .88]$).

Teachers' beliefs

Teachers' beliefs were measured via 12 items adapted from Schmidt and Smidt (2021) on a 5-point Likert scale (1 = *do not agree at all*, 5 = *totally agree*). Three beliefs are distinguished: *co-constructivist beliefs*, e.g. *when supporting children, it is important that teachers and children find out something together*; $\alpha = .77$ ($CI_{95\%} = [.69; .81]$), *autonomy beliefs*, e.g. *when supporting children, it is important that teachers interfere as little as possible*; $\alpha = .57$ ($CI_{95\%} = [.44; .67]$) and *instructivist beliefs*, e.g. *when supporting children, it is important that the children are taught a lot by the teacher*; $\alpha = .78$ ($CI_{95\%} = [.72; .83]$). Despite the low α for *autonomy beliefs*, we decided to maintain the three factors according to the developed instrument and the underlying theory.

Content knowledge

Content knowledge in block play was measured for block play with the Centre-of-Mass Test (Weber & Leuchter, 2020, see Figure 2). The participants were asked to judge whether an asymmetrical block construction would fall or remain stable if a black block was removed. The 16 items could only be correctly solved if knowledge about mass was applied. For every correct answer, participants were awarded one point. The resulting test score, ranging from 0 to 16, served as an indicator for preschool teacher's CK in block play. Internal consistency was $\alpha = .83$, ($CI_{95\%} = [.82; .87]$).

Imagine it is a quiet morning in your daycare center and the children are busy playing quietly with different materials in different places.
Below you see a situation of two (three) children and possible reactions of pedagogical professionals.
Now it is about your personal beliefs. Since this is about your very personal statements or opinions, there are no "right" or "wrong" answers. Simply give the answer to each question that most closely applies to you personally.

Caro, Kim and Luca are playing with building blocks. Kim says to Caro, "If you build it like this, it will fall down."

A: I would go and have a conversation with the kids about what they are doing right now.

B: I would leave the children alone.

C: I would encourage the kids to try next steps in what they do.

D: I would watch the kids silently and write down what they were doing.

E: I would keep the kids to themselves.

F: I would pay close attention to what the children were doing.

FIGURE 1 Example of a vignette. Answers A and C served as indicators for SCAF, D and F as indicators for DIA and B and E as indicators for INA. The participants had to rate their agreement with the statements on a 4-point scale.

Scaffolding practice

Furthermore, we drew a subsample of $N = 73$ preschool teachers who consented to be filmed and videotaped their interaction with a group of two to six children for 30 min. The subsample did not differ from the total sample in the relevant characteristics (age, willingness, beliefs, CK and PCK). Group sizes varied due to different kindergarten sizes, thepresence of the children on the day of data collection and parents who denied videotaping. Preschool teachers were instructed to play freely with building blocks. We applied a global rating of teachers' scaffolding activities to analyse whether they encouraged children to undertake further steps on a 4-point scale (1 = *very low*, 4 = *very high*, see Table 2). Interrater agreement was 95.7% (ICC = .99, $F[22, 23] = 148.0$, $p \leq .001$).

TABLE 1 Items measuring preschool teachers' PCK.

Introductory text	Aspects
A colleague has come up with a concept for block play with a group of children. Below is a list of aspects that your colleague wants to consider. How much do you agree with the ideas of the colleague?	• Physics • Systematizing and ordering • Spatial thinking • Comparing • Making assumptions • Fostering children's reasoning • Promotion of location and direction • Geometrical bodies and forms • Quantities, orders of magnitude, units of measurement • Language

Note: Preschool teachers' PCK was measured on a 4-point Likert scale (1 = do not agree at all and 4 = totally agree).

FIGURE 2 Example items of the COM test (a: unstable, b: stable).

TABLE 2 Rating of preschool teachers' scaffolding activity.

Rating of scaffolding activity	Explanation
1	Preschool teacher does not talk to the children about contexts, concepts are not or inappropriately taught
2	Preschool teacher occasionally talks about logical relationships or concepts, some concepts are taught age and ability appropriate
3	Preschool teacher talks about logical connections, children are encouraged to express their thoughts and are supported by the preschool teacher when solving a problem
4	Preschool teacher PFK supports children's thinking throughout the play, concepts are introduced with reference to the children's situation and interests or to concrete problems that the children have to solve

Note: Preschool teachers' scaffolding was rated independently by two raters on a 4-point Likert scale (1 = very low, 4 = very high).

Statistical procedure

The statistic program R, Version 4.2.1 (R Core Team, 2022) was used for data analysis. Missing values were imputed using the package 'missForest' (Stekhoven & Buehlmann, 2012). We decided to use non-parametric missing value imputation for mixed-type data as we had to deal with continuous as well as categorical variables. In the next step, we recoded the items and estimated reliability

by using the R-package 'car' (Fox & Weisberg, 2019). For data processing and preparation, we used the packages 'psych' (Revelle, 2022), 'tidyverse' (Wickham et al., 2019) and 'dplyr' (Wickham et al., 2022). To validate the instrument for willingness, confirmatory factor analyses were carried out using the package 'lavaan' (Rosseel, 2012). The model was evaluated by inspecting model fit indices (CFI, TLI, RMSEA and SRMR) in additionally to the result of the χ^2 test, as proposed by Hu and Bentler (1999). For data visualization, we used the package 'ggplot2' (Wickham, 2016). To examine correlations, we used the package 'apaTables' (Stanley, 2021). To analyse incremental validity, we computed multiple regression. We checked bivariate correlations of predictors with the criteria to exclude suppression.

RESULTS

Descriptive results

The descriptive statistics are presented in Tables 3 and 4. First, we analysed preschool teachers' learning beliefs. Preschool teachers' approval was highest for the co-constructivist belief and lowest for the instructivist belief. Preschool teachers' willingness to engage in scaffolding activities was lower than their willingness to engage in diagnostic activities. Preschool teachers' CK in block play was rather low with $M = 10.03$ ($SD = 3.66$) dichotomous items solved out of 16. Participants performed slightly above chance level ($M = .63 > \mu = .5$; $t[150] = 6.81$, $p \leq .001$). PCK in block play was rather high ($M = 33.78$; $SD = 3.41$; Max = 40). Preschool teachers' scaffolding activity was moderate ($M = 2.15$, $SD = 1.06$, Min = 1, Max = 4).

TABLE 3 Descriptive results for learning beliefs.

	M	*SD*	Min	Max
Learning beliefs				
To support children's learning and development it is important that…				
Co-constructivist beliefs				
The children are encouraged by the teacher to find their own solutions	4.62	.45	3	5
Teachers and children exchange information on an equal footing	4.48	.52	3	5
The children are made to think through the conversation	4.66	.52	2	5
Teachers and children find out something together	4.21	.72	2	5
Autonomy beliefs				
The initiative comes from children	4.24	.62	2	5
Teachers interfere as little as possible	3.69	.68	1	5
Each child chooses his or her own tasks	3.74	.61	2	5
The children educate themselves from themselves	3.98	.65	1	5
Instructivist beliefs				
The teacher dictates what the children should do	1.92	.72	1	4
The children are taught a lot by the teacher	2.92	.72	1	5
The initiative comes from the teacher	2.49	.64	1	4
Children carry out the instructions of the teacher	2.37	.79	1	5
Co-constructivist beliefs	4.48	.43	–	–
Autonomy beliefs	3.91	.43	–	–
Instructivist beliefs	2.43	.56	–	–

Note: Learning beliefs were measured on a 5-point-Likert scale (1 = do not agree at all, 5 = totally agree).

TABLE 4 Descriptive results for the vignettes (VIG).

	M	*SD*	Min	Max
Vignettes				
VIG1: Chantal and Pascal are sitting on the seesaw. Chantal says to Pascal, 'Make yourself really heavy'				
DIA	**3.66**	**.44**	**1**	**4**
SCAF	2.52	.53	1	4
INA	2.80	.62	1	4
VIG2: Sarah, Annika and Kevin are looking at a picture book. Sarah points to a page and says to Kevin and Annika, 'Look, there are as many magnets on this refrigerator as there are in our house'				
DIA	**3.54**	**.54**	**1**	**4**
SCAF	2.64	.56	1	4
INA	2.79	.63	1	4
VIG3: Mesut, Lia and Michelle are playing with picture cards. Mesut says to Lia, 'I drew a candle, it's really soft'				
DIA	**3.49**	**.51**	**1**	**4**
SCAF	2.64	.54	1	4
INA	2.76	.63	1	4
VIG4: Caro, Kim and Luca are playing with building blocks. Kim says to Caro, 'If you build it like this, it will fall down'				
DIA	**3.59**	**.45**	**2**	**4**
SCAF	2.68	.51	1	4
INA	2.78	.64	1	4
VIG5: David, Fatima and Jonas are playing with the marble run. Jonas says to Fatima and David, 'My marble is definitely the fastest'				
DIA	**3.51**	**.52**	**1**	**4**
SCAF	2.67	.56	1	4
INA	2.89	.60	1	4
DIA	3.56	.46	–	–
SCAF	2.66	.41	–	–
INA	2.80	.54	–	–

Note: The participants had to rate their agreement with the statements on a 4-point scale ($N = 151$). The highest means are printed in bold. VIG = Vignette, SCAF = willingness to engage in scaffolding, DIA = willingness to engage in diagnostic, INA = inactivity.

Does the instrument for assessing willingness differentiate validly between diagnosis, scaffolding and inactivity?

We tested the instrument for assessing willingness for the suggested three-dimensional model comprising Diagnosis (DIA), Scaffolding (SCAF) and Inactivity (INA). On account of the small number of observations ($N = 151$), the specified item-based model did not converge. Thus, 6-item parcels consisting of 5 items with two items per vignette per parcel were built. The first parcel consisted of the dimensions' first items and the second parcel of the dimensions' second items, aggregated over all 5 vignettes. The resulting three-dimensional model yielded an acceptable fit, $\chi^2(6) = 15.68$, $p = .016$; CFI = .987; TLI = .967; RMSEA = .10; SRMR = .04. CFI, TLI and SRMR fell above the cut-offs proposed by Hu and Bentler (1999) and thus indicate a good fit. However, the chi-square/df ratio exceeds factor 2. The RMSEA as a badness-of-fit index was slightly above the recommended cut-off (.10). These deviations might be due to small degrees of freedom and sample size and do not necessarily indicate a bad fit (Kenny et al., 2015; Kyriazos, 2018). Thus, goodness-of-fit indices and intercorrelations (Figure 3) suggest factorial validity of the three-dimensional model, which is in accordance with the results of the exploratory factor analysis in our pilot study.

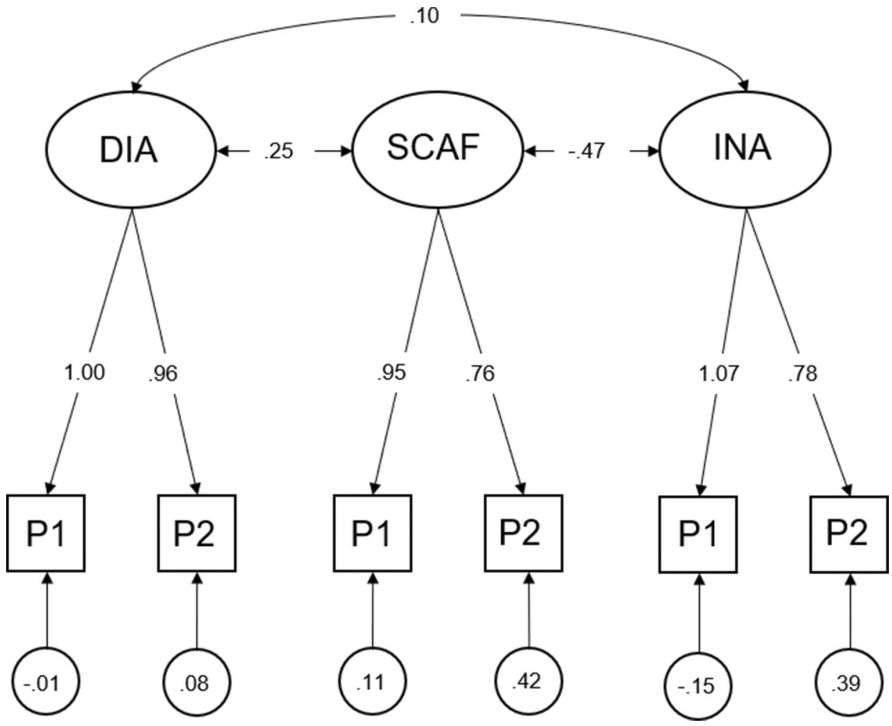

FIGURE 3 Factor loadings and residual variances of the tested three-dimensional model.

How are preschool teachers' CK, PCK, learning beliefs, willingness and their practice related?

To answer the second research question, correlations between the investigated variables were examined based on $N = 151$ observations (Table 5). Co-constructivist beliefs were negatively correlated with age; however, co-constructivist and autonomy beliefs were positively related. The correlation between autonomy beliefs and instructivist beliefs was negative. Willingness to engage in DIA was positively correlated with co-constructivist beliefs, autonomy beliefs and PCK. Furthermore, willingness to engage in SCAF was positively associated with co-constructivist beliefs and PCK. PCK showed a negative association with INA and CK. Moreover, we examined the correlations between scaffolding performance measured via video analyses (video) and all other variables based on $N = 73$ observations. Age correlated with scaffolding performance: the older the preschool teachers, the more they were involved in children's play by asking them questions and encouraging them to undertake further steps. However, the other variables were not significantly correlated. As group sizes varied substantially between preschool teachers, we examined the correlation between group size and preschool teachers' scaffolding practice, which was not significant ($r = .04$, $p = .743$).

Which variables showing significant bivariate correlations bear incremental validity in the prediction of willingness to engage in scaffolding, diagnosis and inactivity?

Multiple regression analyses were performed for the dependent variables with more than one significant correlation based on $N = 151$ observations (Table 3). Autonomy beliefs were not related to willingness when accounting for co-constructivist beliefs and PCK, which, in turn, were related to willingness to engage in DIA (Table 6). The model accounted for 25% of variance ($R^2_{adj.} = .25$, $F[3, 147] = 17.37$, $p \leq .001$).

TABLE 5 Results of the correlation analysis.

	Variable	1	2	3	4	5	6	7	8	9	10
	1. Age										
	2. Diploma	−.10									
Willingness	3. DIA	.07	.07								
	4. SCAF	.11	.18	**.28**							
	5. INA	−.04	−.23	.12	**−.33**						
Learning beliefs	6. Instr.	.01	−.01	−.13	.04	.08					
	7. Co-constr.	**−.27**	.07	**.40**	**.29**	−.10	−.18				
	8. Autonomy	−.14	−.24	**.25**	−.14	.01	**−.38**	**.30**			
Knowledge	9. CK	.04	.16	−.15	−.11	−.22	−.11	.05	−.18		
	10. PCK	−.07	−.09	**.30**	**.32**	**−.26**	.12	.21	.05	**−.25**	
	11. Video	**.46**	.05	.08	.08	−.05	.20	−.17	−.17	.04	−.03

Note: Significant correlations are printed in bold.

TABLE 6 Results of the multiple regression analyses on DIA.

Variables	*B*	*SE* (*B*)	*t*	*p*
Autonomy	.17	.20	.85	.394
Co-construction	.89	.22	4.11	≤.001***
PCK	.34	.10	3.37	≤.001***

Note: *$p < .005$, **$p < .01$, ***$p < .001$.

TABLE 7 Results of the multiple regression analyses on SCAF.

Variables	*B*	*SE* (*B*)	*t*	*p*
Co-construction	.17	.20	.86	.389
PCK	.36	.10	3.62	≤.001***

Note: *$p < .005$, **$p < .01$, ***$p < .001$.

Results suggested that co-constructivist beliefs were not related to willingness when accounting for PCK, which, in turn, was related to willingness to engage in SCAF (Table 7). The model accounted for 10% of variance ($R^2_{adj.} = .10$, $F[2, 148] = 9.15$, $p \leq .001$).

DISCUSSION

Research on preschool teachers' willingness to engage in science learning situations has been sparse. Thus, the purpose of this study was to assess preschool teachers' willingness to engage in diagnostic and scaffolding activities through developing an instrument and to examine its relations to learning beliefs, CK, PCK and practice.

Our results show that our proposed three-dimensional factor structure of willingness was valid. Teachers, who were willing to engage in diagnosis, were also willing to engage in scaffolding activities. However, when willing to engage in scaffolding activities, they were not willing to stay inactive. Moreover, our analyses demonstrated that preschool teachers favoured to engage in diagnostic activities rather than to engage in scaffolding. We assume that preschool teachers' high willingness to engage in diagnosing is an indicator of the socio-pedagogic tradition in Germany (e.g. ECEC/OECD, Anders, 2015). From this tradition, leaving the children on their own and intervening as little as possible is an appropriate situation for diagnosing. Besides, willingness to stay inactive was slightly higher than

willingness to engage in scaffolding, which further underpins this assumption. We cannot rule out that other pedagogic traditions might interfere with preschool teachers' willingness to engage in diagnosing or scaffolding differently and thus produce alternative results.

Moreover, we found consistencies within teachers' beliefs. The correlations between learning beliefs were coherent as we found teachers with co-constructivist beliefs to score higher in autonomy beliefs and to score lower in instructivist beliefs. Furthermore, our analyses suggest that co-constructivist beliefs were more common than autonomy beliefs in contrast to the socio-pedagogic tradition in Germany (e.g. ECEC/OECD, Anders, 2015). This finding is in line with Perren et al. (2017) and Schmidt and Smidt (2021), who found that preschool teachers held mostly co-constructivist beliefs. Contrary to other studies, we cannot find empirical evidence that preschool teachers held instructivist beliefs (Leuchter et al., 2020; Rank, 2009; Yin et al., 2020).

The interplay between beliefs, willingness and practice was consistent as teachers with co-constructivist beliefs seemed to be more willing to engage in scaffolding. Besides, analogous to teachers' willingness to stay inactive, video analyses uncovered that teachers' scaffolding activities were rather infrequent, which corresponds to current literature about preschool teachers' low instructional quality (Piasta et al., 2014; Roth, 2014). However, we also found inconsistencies when taking a closer look at the correlations between age, beliefs and practice. The older preschool teachers were, the less they valued co-constructivist beliefs. At the same time, our video analyses suggested that the use of scaffolding techniques significantly increased with age. Moreover, co-constructivist beliefs did not predict preschool teachers' classroom practice. However, co-constructivist beliefs were positively associated with teachers' willingness to engage in diagnosis and scaffolding. Additionally, we found a positive association between preschool teachers' co-constructivist beliefs and their PCK which failed to meet the significance criterion. This finding is in line with the study of Leuchter et al. (2020) who found that teachers who held highly co-constructivist beliefs ranked higher in PCK. Nevertheless, when considering teachers' PCK, their co-constructivist beliefs did not predict their willingness to engage in scaffolding. However, both, co-constructivist beliefs and teachers' PCK related to their willingness to engage in diagnosis. This implies that teachers' PCK might be more important for their willingness to engage in diagnosis and scaffolding than their learning beliefs. A reason for this might be that teachers holding co-constructivist beliefs show lower associations between beliefs and practice than teachers holding instructivist beliefs (Mansour, 2013). In our study, the relationship between instructivist beliefs and practice was positive but failed to meet the significance criterion. These results might reflect the high demands of putting co-constructivist beliefs into action. An additional issue may be that we analysed our data across five science contexts while some authors have argued that beliefs represent context-specific assumptions (Leuchter et al., 2020). Besides, teachers' educational quality might differ in different situations (e.g. lunchtime vs. block play; Reyhing & Perren, 2023): Thus, the associations between teachers' dispositions (knowledge and beliefs) and their practice might be strongly dependent on the context.

Summarizing, this study showed that PCK is related to preschool teachers' willingness to engage in diagnostic activities across science contexts as well as in block play. However, age was more important than PCK for teachers' use of scaffolding techniques in block play. One explanation for the missing relationship between preschool teachers' PCK and their practice might be that preschool teachers have difficulties in recognizing science learning opportunities, which is a prerequisite to engage in learning support (Samuelsson & Carlsson, 2008). PCK is not only related to the implementation of scaffolding techniques but also to the sensitivity towards science contents and learning opportunities and exerts a cross-context influence on practice (Cabell et al., 2013; Hamre et al., 2014; von Suchodoletz et al., 2014). Interestingly, when we moved away from preschool teachers' self-reported dimensions, the associations between scaffolding practice and willingness to engage in scaffolding remained rather small. Hence, we corroborate research which has found small associations between teacher dispositions and practice (Mohamed & Al-Qaryouti, 2016; Stipek & Byler, 1997; Waters-Adams, 2006).

Limitations

We employed five vignettes to measure willingness to engage in diagnosis and scaffolding. Hence, only a small number of science learning opportunities were examined. More vignettes with varying content and open-ended questions would increase the predictive power and validity of our study (e.g. including literacy and reading skills).

Pedagogical content knowledge was measured via statements of appropriateness, thus, preschool teacher answers might have been affected by social desirability. The same problem accounted for the self-report of willingness to engage in scaffolding. However, the detrimental effect of social desirability on validity seems to be smaller than previously thought (Paunonen & LeBel, 2012). As we decided to put willingness in the focus of our study, we applied a global rating of frequency and quality of scaffolding in our video analyses. Future studies should examine scaffolding activities more precisely by considering appropriateness and sensitivity of timing. We might have missed context-specific characteristics, which could contribute to a clarification of the interplay between beliefs and practice. As data acquisition took place during the COVID-19 pandemic, we had to deal with missing data which led to a reduction in sample size and to a loss of power for our statistical analyses. To account for this circumstance, items for the CFA were parcelled, and missing data were imputed. Nevertheless, the results of CFA were backed up by our pilot study. Future studies should examine more pathways, which mediate the association between dispositions and practice (e.g. self-efficacy; Reyhing & Perren, 2023).

CONCLUSION

Our findings contribute to the literature on early science education and preschool teachers' professional competences as the introduced instrument might be a promising and low-effort approach to measure preschool teacher's willingness to engage in early science learning. Our study addresses the gap between preschool teachers' dispositions (i.e. knowledge, beliefs, willingness) and their practice, which contributes to the literature on early science learning. We have shown that preschool teachers with higher PCK were more willing to engage in diagnosis and scaffolding. However, we found inconsistencies between preschool teachers' age, beliefs and practice, which calls for further clarification.

AUTHOR CONTRIBUTIONS

Anke Weber: Conceptualization; project administration; writing – review and editing. **Laura Venitz:** Writing – original draft. **Lukas Schmitt:** Conceptualization; data curation; formal analysis; investigation; methodology; software; validation; visualization; writing – original draft; writing – review and editing. **Miriam Leuchter:** Conceptualization; funding acquisition; project administration; supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

As we deal with sensitive data from kindergartens that affects the rights of third parties, the data will not be made publicly available.

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