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First Insights into Preschool Teachers' Instructional Quality in Block Play and Its Associations with Children's Knowledge, Interest, Academic Self-Concept and Cognitive Aspects

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ABSTRACT

Research Findings: Promoting children's science knowledge by adequate measures such as guided or free play is a cardinal goal of preschool. However, there is considerable variability in preschool teachers' instructional quality in block play, which might be associated with children's domain-specific science skills but also their mathematic and language achievement. To examine preschool teachers' instructional quality in a free block play episode we used a video-based assessment. We assessed children's knowledge in block play along with mathematics, language capacity, self-concept and cognitive skills. In order to obtain first insights into the association between teachers' practice and children's knowledge, we took a correlational approach. The sample consisted of $N = 73$ preschool teachers and $N = 431$ children. The results revealed considerable differences between preschool teachers' instructional quality. Overall instructional quality during block play as well as specific dimensions such as the use of spatial language, math language and cognitive activating scaffolding were positively associated with children's stability knowledge in block play. Moreover, preschool teachers' general language use and stimulation of communication as well as their sensitivity were positively associated with children's self-concept in block play. *Practice and policy*: Our study emphasizes the importance of preschool teachers' support for children's knowledge and self-concept and expands prior findings on early science learning.

Theory

Promoting children's school readiness by age-adequate means is a fundamental goal of preschool. Teacher-child-interactions are considered a foundation for promoting children's development in e.g., cognitive and motivational facets (e.g., Weisberg et al., 2016). Children develop their own intuitive theories to explain the world around them and continuously adjust these theories as they gain new knowledge (Gopnik & Wellman, 2012). To support children's science learning, it is important to consider developmental constraints and to incorporate everyday activities, such as play (Zosh et al., 2018). One way to implement early science learning with young children is through block play, which offers the opportunity to foster children's concepts about stability, spatial knowledge as well as mathematical knowledge (e.g., A. M. [Author] et al., 2020; Borriello & Liben, 2018; Casey et al., 2008; Gunderson et al., 2012; Levine et al., 2012; Park et al., 2008; Verdine et al., 2014). Spatial abilities are important prerequisites for children's science, technology, engineering and math (STEM) learning (Uttal

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et al., 2013). Besides, children's concepts about stability in block play are used in early science classrooms for example when integrating engineering play (e.g., Gold et al., 2020). Yet, research has shown that kindergarten-aged children predominantly hold misconceptions about stability (e.g., A. M. [Author] et al., 2020). To further enhance children's learning, teachers can provide scaffolding during play, either through providing materials (e.g., building blocks) or through verbal support or through combining both (e.g., van de Pol et al., 2010; Weisberg et al., 2016). Most important, providing children with high quality learning support has been identified as a core aspect of preschool teachers' professional competence (e.g., Anders et al., 2013). However, preschool teachers face problems supporting children's learning, especially in early science, as they often feel ill-prepared for the task (Spektor-Levy et al., 2013). Studies how a considerable variance in preschool teachers' instructional quality in early science (Pianta et al., 2008) and in block play (e.g., Trawick-Smith et al., 2017).

To the best of our knowledge, there has been no study which has simultaneously investigated the association between preschool teachers' instructional quality in block play and children's learning of stability, mathematics and language. To date, most of the research on block play has focused either on its relationship to spatial skills (e.g., Casey et al., 2008; Ferrara et al., 2011; Yang & Pan, 2021) or to mathematics (e.g., Verdine et al., 2014). In our study, we considered $N = 73$ preschool teachers' instructional quality, and $N = 431$ children's knowledge, interest and self-concept in block play as well as mathematical skills, spatial language and cognitive abilities (fluid and crystallized intelligence and working memory).

Block Play in Kindergarten

Block play is considered to be an everyday situation in German kindergartens that teachers can use to interact with children and integrate early learning opportunities (e.g., spatial learning, mathematical learning). However, research about the frequency of block play in kindergartens remains sparse to date. There are studies advocating that preschool teachers use block play to foster children's mathematical and spatial learning, and particularly the development of social skills (for an overview, see Henschen & Henschen, 2020). Socio-emotional approaches, which have been particularly prominent in Germany, prioritize the development of children's socio-emotional skills (ECEC/OECD, Anders, 2015). Nevertheless, preschool teachers' professionalization in the recent years has focused more on teaching early mathematics and science (Mischo & Fröhlich-Gildhoff, 2011), albeit the transmission of pedagogical knowledge is still an overarching goal.

Instructional Quality and Child Outcomes

Preschool teachers' instructional quality has been of major interest in educational research and is discussed as one of the key determinants of children's learning gains (e.g., Goble et al., 2019; Y. Guo et al., 2011; Schlesinger & Jentsch, 2016). However, there is little consensus about the conceptualization and measurement of instructional quality regarding context-specificity (i.e., subject-dependency), dimensionality (i.e., whether it is multifaceted and which dimensions should be considered) and observed practice (see the review by Senden et al., 2022). Research has shown that instructional quality is no one-way street and is determined by both, teacher and child behavior. For example, children's motivation has shown to have a positive impact on instructional quality (Scherer & Nilsen, 2016). Nevertheless, challenging learner's cognition by age-appropriate measures has been identified consistently as a core aspect of high instructional quality across classes and ages (Senden et al., 2022).

One way to provide challenging learning support may be through cognitive activating scaffolding (for an overview, see van de Pol et al., 2010). Based on van de Pols theoretical framework, there are studies, which have conceptualized scaffolding for early science learning (e.g., A. M. [Author] et al., 2020; Monteira et al., 2022). Studies suggest that children benefit from verbal scaffolds during guided play more than when playing freely without verbal scaffolding (e.g., A. M. [Author] & [Author], 2020; Fisher et al., 2013). In the context of block play, M. [Author] et al. (2020) showed that children's learning can be fostered by verbal scaffolding techniques. For example, preschool teachers might activate prior knowledge or focus children's attention to facilitate their learning (e.g., A. M. [Author] et al., 2020). Applying cognitive activating scaffolding encompasses the deliberate use of language to stimulate children's thinking (e.g., the use of spatial and mathematical language in block play). Spatial language refers to the use of words and phrases that describe the spatial relationships between objects, e.g., referring to height or spatial orientation of the blocks (e.g., Ferrara et al., 2011). Math language refers to the specific terminology used in mathematics, such as addition, subtraction, or geometric terms, e.g., when counting blocks or foster children's geometric understanding when comparing shapes (e.g., Ferrara et al., 2011; Klibanoff et al., 2006). Thus, spatial and math language can be used in block play to foster children's learning. In sum, teacher-led activities, which include cognitive activating scaffolding, enhanced teacher-child instructional quality (Smidt & Embacher, 2020). However, studies have shown that preschool teachers' use of cognitive activating scaffolds varies considerably (Hamre et al., 2014; Pianta et al., 2008).

Recent studies have focused on the association between teachers' general instructional quality and children's learning outcomes (Senden et al., 2022). However, research on a causal link between instructional quality and children's achievement is ambiguous. A study of Weiland et al. (2013) with 414 children attending Boston public preschools could not find any associations between preschool classroom quality and children's language, literacy or mathematical skills. Further, Duncan et al. (2015) examined whether the fading-out of rather short-term learning gains in preschool could be reduced by higher instructional quality and found no effect. However, research has shown that the quality of language and literacy instruction in preschool was commonly low, with only few teachers delivering high-quality instruction (Burchinal et al., 2008; Justice et al., 2008). This finding might account for the lack of significant associations between high quality teaching and children's learning gains. By contrast, Hall-Kenyon et al. (2009) provide an alternative explanation for the lack of association between instructional quality and learning outcomes: They have shown that the impact of instructional quality on children's achievements is rather subject-specific than generic and related to the impact of other confounding variables (e.g., presence of children, full vs. half day classrooms and children's attentiveness and social background).

However, some studies have indicated that high-quality instructional interactions targeting children's higher order thinking, language and conceptual understanding were associated with positive outcomes for preschoolers (e.g., Kook & Greenfield, 2021). With the focus on language acquisition, preschool teachers' language and literacy instructional quality was positively associated with children's vocabulary gains (Y. Guo et al., 2011). This finding is in line with the results of Mashburn et al. (2008) who have reported that preschool teachers' instructional interactions predicted preschoolers' language achievement and thus facilitated school readiness. Additionally, studies have revealed that sensitive and stimulating interactions fostered children's language acquisition and pre-academic skills (Burchinal et al., 2008).

With the focus on math learning, several studies have shown positive associations between instructional quality and math achievement (e.g., Anders et al., 2013; Lehrl et al., 2016). Nonetheless, the quality of preschool teachers' mathematical instructions has shown to be rather low (e.g., Cerezci, 2020). Two longitudinal studies have examined the effect of early mathematical instructional quality on children's mathematical achievement in Germany. Lehrl et al. (2016) have found that instructional quality in preschool predicted children's increase in mathematical knowledge in grade 1 to 3. Anders et al. (2013) could show that beneficial effects of high mathematical instructional quality in preschool lasted from age 3 at least until the end of the first class of elementary school. Moreover, this effect was independent of the instructional quality in mathematics in primary school and thus underlines the importance of fostering children's early mathematical learning. These results are supported by Stipek and Chiatovich (2017) who have shown that high instructional quality in preschool predicts reading and mathematical achievement in class 3.

Preschool teachers need to apply a combination of verbal support, contingent feedback and sensitivity to provide effective teaching and to foster children's self-concept and interest in science learning (Lepper et al., 2005; Stipek et al., 1995). Besides, research has shown that teachers' general language use is associated with children's academic outcomes, such as reading and general language skills (e.g., Dickinson, 2011; Dickinson & Porche, 2011). Furthermore, researchers in the field of early science learning argue that preschool teachers need to establish a joyful atmosphere, integrating early science learning into children's play (e.g., Lepper et al., 2005; Samuelsson & Johansson, 2006). Additionally, findings suggest that teachers' sensitivity in providing responsive feedback and warm interactions is an integral part of effective preschool teaching (e.g., Birch & Ladd, 1997; Downer et al., 2010). When teachers are sensitive to children's needs, they can create a safe and supportive learning environment that fosters children's self-concept and engagement in learning. A study by Pianta and Stuhlman (2004) found that preschool children who had sensitive teachers were more likely to be enthusiastic and engaged in learning activities, and less likely to display negative social behaviors in grade one. To account for these perspectives on instructional quality, there are instruments available to rate preschool teachers' use of language, teachers' stimulation of communication and their joy during teacher-child-interactions (e.g., Early Child Environment Rating Scale Revised Edition (ECERS-R), Harms et al. (1998); in German: Kindergarten-Skala. Revidierte Fassung mit Zusatzmerkmalen (KES-RZ), Roßbach et al. (2017), as well as sensitivity (Erickson-Scales, Egeland et al., 1990).

In sum, empirical evidence points toward an effect of instructional quality on children's domain-specific learning gains and self-concept. The combination of different conceptualizations may allow for a detailed and broad picture of teachers' instructional quality. Thus, we decided to take a multifaceted view on teachers' instructional quality by considering their use of language to stimulate children's thinking as well as their general language use, expressed joy and sensitivity to foster children's self-concept and learning. Nevertheless, the impact of teacher professionalization on children's learning gains is still a desideratum in educational research (e.g., Wullschleger et al., 2022). In our case, it remains unclear whether instructional quality in block play is associated with children's achievement of stability knowledge, mathematics and language skills.

Aspects of Children's Knowledge in the Context of Block Play

Knowledge of Stability

In our study, we focus on children's knowledge about stability. According to Bonawitz et al. (2012), three theories about stability can be differentiated: (1) the consideration of the geometrical center for assessing stability, (2) the use of an object's center of gravity (mass) for assessing stability and (3) an undifferentiated pattern of guessing with no consistent theoretical explanation. For the correct estimation of a symmetrical object's stability, it is sufficient to consider the object's geometrical center (see Figure 1). If the geometrical center is supported by an underlying surface, the symmetric object will remain stable. However, for the correct estimation of an asymmetrical objects' stability, the objects' mass distribution must be considered, because their geometrical center does not correspond to their center of mass. If the center of mass is not supported by an underlying surface, the asymmetrical object will tumble, regardless of the support of its geometrical center (see Figure 1).

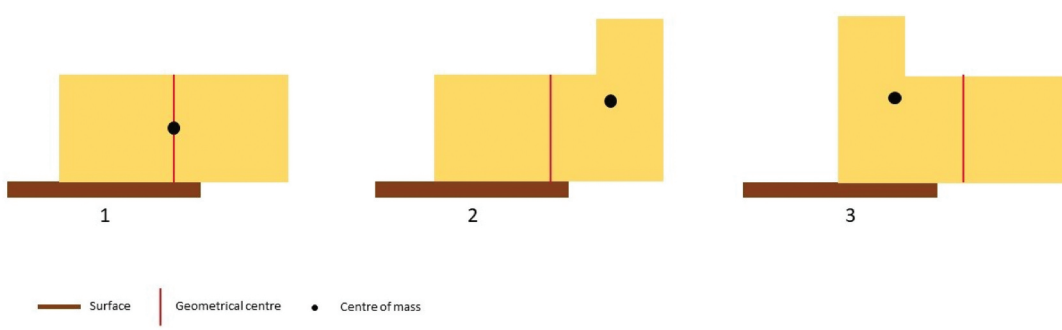


Figure 1. Stability of symmetrical (1 on the left, stable) and asymmetrical objects (2 in the middle, unstable, 3 on the right, stable).

M. [Author] et al. (2020) have shown that more than half of 5- to 6-years-old children did not use a consistent theory to predict stability and less than 20% of the children could be classified as mass theorists. 43% were identified as center theorists (A. M. [Author] et al., 2020). The finding that most pre-school children do not use mass theory to predict stability is supported by other studies (e.g., Bonawitz et al., 2012; Krist, 2010, 2013; Krist et al., 2005, 2018). Moreover, research has shown that children perform better on symmetrical objects than for asymmetrical ones (Krist, 2010; Krist et al., 2005). Although the studies used different paradigms to assess children's knowledge about mass such as pictures (A. M. [Author] & [Author], 2020), real stimuli (Krist, 2010, 2013), physical action (Bonawitz et al., 2012; Krist et al., 2005) or eye-tracking (Krist et al., 2018), they all reflect young children's limited capability to consider an object's mass when assessing stability. There is evidence that children's use of mass theory increases with age (Bonawitz et al., 2012; Krist et al., 2005, 2018) and can be fostered by playful interventions (Pine & Messer, 2003). However, these studies neglect ecological validity and thus do not integrate preschool teachers' instructional quality in block play when analyzing children's stability knowledge. Yet, the substantial variability of preschool teachers' instructional quality in block play (e.g., Trawick-Smith et al., 2017) might be associated with children's theories about stability.

Spatial Language

Block play bears the opportunity to foster spatial learning with a low-threshold and age-appropriate approach (Borriello & Liben, 2018; Ferrara et al., 2011; Jirout & Newcombe, 2015). For example, preschool teachers can use spatial terms referring to height or spatial orientation of the blocks (e.g., Ferrara et al., 2011) or apply cognitive activating scaffolding measures that encourage children to give explanations or evoke their prior knowledge about spatial principles (e.g., M. [Author] et al., 2020). Language in block play can include positions of objects in relation to each other, geometric properties, distances, units of measurements and prepositions (L. E. Cohen & Emmons, 2016; Ferrara et al., 2011). There is evidence that the use of spatial language supports children's spatial reasoning and the development of spatial skills (e.g., Ferrara et al., 2011). Moreover, spatial skills are an integral predictor of young children's later science and mathematics achievement (Uttal & Cohen, 2012). However, studies on supporting spatial knowledge through block play have focused on parent-child (Borriello & Liben, 2018; Ferrara et al., 2011) or researcher-child interactions (M. [Author] et al., 2020), while studies on teacher-child interactions during block play remain sparse (Casey et al., 2008). However, the variance of preschool teachers' use of spatial language might be associated with children's language development and their spatial skills (e.g., Casey et al., 2008).

Mathematical Knowledge

Studies have demonstrated that a semi-structured block play intervention can foster children's mathematical knowledge (Schmitt et al., 2018). Further evidence for the effectiveness of interventions in the context of block play for math achievement stems from studies which have employed building blocks and geometric shapes (e.g., Fisher et al., 2013; Verdine et al., 2014). Additionally, studies suggest that children's early spatial skills are predictive for later math achievement (e.g., Moehring et al., 2021; Zhang & Lin, 2017). Quantitative and spatial words related to mathematical skills are typically labeled as "Math Talk" (e.g., Klibanoff et al., 2006). Block Play bears the opportunity to talk about numbers (e.g., counting blocks), geometric shapes (e.g., triangles, rectangles), measures (e.g., height in cm) or to carry out basic mathematical operations (e.g., addition, subtraction). On this basis, we assume that children's achievement not only in stability knowledge but also in math language and corresponding spatial knowledge might be fostered through block play. Research has shown that the amount of Math Talk predicts children's growth in mathematical knowledge (e.g., Hornburg et al., 2018; Klibanoff et al., 2006; Moffett & Eaton, 2017; von Spreckelsen et al., 2019). However, the amount of mathematical language seems to vary considerably between preschool teachers (Johnston & Degotardi, 2022; Klibanoff et al., 2006; Rudd et al., 2008).

Interest

Children show a natural interest in science phenomena such as block play which is a good starting point for the promotion of their science knowledge (e.g., Trundle & Saçkes, 2015). Children who are interested in a particular topic are more likely to engage with the content and seek deeper understanding than children who are uninterested (Renninger & Hidi, 2016). Therefore, it is probable that children with higher levels of interest in the stability of blocks perform better than uninterested children in stability knowledge, in spatial language and corresponding math knowledge. For block play, research has shown a greater interest for boys to play with blocks (A. M. [Author] & [Author], 2020; Saracho, 1994).

Academic Self-Concept

Research has shown that block play is a motivating context for children's learning (Weisberg et al., 2016). According to Marsh et al. (2002), the academic self-concept is made up of competence and motivational beliefs and regarded as an important component of children's development which are associated with performance (e.g., Marsh et al., 2012). Theories exploring the relationship between motivation and achievement, like expectancy-value theory (Eccles et al., 1983), consider motivation as a component of value, while competence beliefs fall under the expectancy facet. According to this theory, motivation and competence are substantially interconnected and influence knowledge acquisition (Eccles et al., 1983). Children favor activities, in which they are convinced of their capability to be successful (e.g., A. M. [Author] & [Author], 2020; Marsh et al., 2012) and highly motivated children with strong expectancies tend to be more persistent and determined in overcoming learning obstacles (J. Guo et al., 2015; Marsh et al., 2005) and. This association seems to strengthen over time, especially in elementary school (Wigfield et al., 1997). Thus, in our study, we considered motivational beliefs as a part of children's academic self-concept. Research has shown that girls' self-concept in block play is less pronounced than those of boys (A. M. [Author] & [Author], 2020). However, preschool children in general tend overestimate their skills, leading to rather high academic self-concepts in early science (e.g., Harter, 2015).

Intelligence and Working Memory

A considerable variance in children's achievements is explained by cognitive variables (e.g., intelligence), which is one of the most important predictors for learning and later academic achievement (e.g., Fergusson et al., 2005; Schneider & Preckel, 2017). According to Cattell (1987), fluid intelligence consists of the ability to think logically and to solve problems independently of previously acquired knowledge. Fluid intelligence comprises figural reasoning and perception and might thus be associated with children's stability knowledge and math knowledge. Besides, we expect substantial correlations between children's crystalline intelligence and their use of spatial language, as language-related subtests are usually used as indicators for crystallized intelligence (e.g., Petermann & Daseking, 2018). Moreover, higher crystallized intelligence should facilitate children's learning not only in a specific domain, but also in other pre-academic fields (e.g., mathematics). Crystallized intelligence increases with age and depends, compared to fluid intelligence, more on external factors (Rindermann et al., 2010), and might thus be associated with teachers' support. Accordingly, research has shown that crystallized intelligence is less associated with working memory than fluid intelligence (Swanson et al., 2008).

Working memory is considered to be an important factor as well when predicting children's achievement even if studies control for intelligence (e.g., Andersson, 2008). Findings suggest that young children's working memory exerts an influence school achievement in mathematics (e.g., Emslander & Scherer, 2022; van den Bos et al., 2013), language (e.g., St Clair-Thompson & Gathercole, 2006) and reading (Swanson, 2008; Titz & Karbach, 2014), respectively. Furthermore, research has shown that working memory is related to visuospatial and analytic problem-solving (e.g., Fleck, 2008; Passolunghi & Mammarella, 2012). Therefore, we examined the association between children's working memory and their stability knowledge in the context of block play.

Rationale of the Study

In our study, we have focused on children's cognitive and self-related aspects in the context of block play as gatekeepers to STEM-learning. The importance of self-concept, interest and motivation for STEM learning has been shown consistently (cf. J. Guo et al., 2015; Marsh et al., 2012). Based on the reciprocal effects model proposed by Marsh and Craven (2006), there is a mutual relationship between academic self-concept and knowledge acquisition in a specific area, such as block play. Consequently, children's academic self-concept affects subsequent knowledge acquisition, and vice versa (Marsh et al., 2012). Children with a strong self-concept and interest in block play might tend to engage in block building activities more frequently and may challenge themselves with more difficult tasks (e.g., A. M. [Author] & [Author], 2022). These children may display a greater willingness to take risks, experiment with different approaches, and persist in problem-solving, as they are motivated by their own internal drive and enjoyment of the activity. Their confidence in their abilities may contribute to a more intensive engagement with block play, fostering opportunities for skill development. However, despite the growing body of research on the potential impact of block play in fostering spatial learning, spatial language, math knowledge, and stability knowledge (e.g., A. M. [Author] & [Author], 2022; Borriello & Liben, 2018; Fisher et al., 2013; Park et al., 2008; Wolfgang et al., 2001), there is still a lack of studies exploring the connection between young children's self-concept and their skill development. Thus, we examined whether children's self-concept was associated with their skill development, i.e., knowledge about stability, spatial language and math knowledge. Besides, by incorporating spatial and mathematical vocabulary associated with the height or orientation of blocks (Ferrara et al., 2011) or basic mathematical operations (e.g., Klibanoff et al., 2006) and employing cognitive scaffolding strategies that prompt children to articulate and utilize their existing spatial knowledge (A. M. [Author] et al., 2020), preschool teachers have the potential to enrich spatial learning experiences. Studies indicate that the integration of spatial language facilitates the advancement of children's spatial reasoning abilities and skill development (Ferrara et al., 2011). From that, we assume that children's spatial language ability might be associated with their stability knowledge too. Children's spatial skills, in turn, have shown to be associated with interindividual differences in math knowledge (e.g., Bull et al., 2008; Rittle-Johnson et al., 2019). Hence, we examined the interplay between children's math knowledge, spatial language and stability knowledge. Moreover, cognitive aspects (i.e., intelligence and working memory) were considered as background variables, which may influence children's knowledge acquisition (Thorsen et al., 2014). Ultimately, research has shown that teachers' instructional quality and the use of cognitive activating scaffolding (Hamre et al., 2014; Pianta et al., 2008), spatial language (cf. Casey et al., 2008) and math language (Johnston & Degotardi, 2022; Rudd et al., 2008) varies considerably. However, it remains unclear whether teachers' overall instructional quality or specific dimensions of instructional quality are associated with children's cognitive or self-related aspects. Nevertheless, studies have indicated that structured interventions with building blocks and geometric shapes can enhance children's stability knowledge (e.g., A. M. [Author] et al., 2020; Pine & Messer, 2003), spatial knowledge (Ferrara et al., 2011) and math knowledge (Fisher et al., 2013; Schmitt et al., 2018).

Given these theoretical assumptions, we aim to provide first insights into the associations between children's cognitive and self-related aspects (research question 1) as well as the associations between preschool teachers' instructional quality in block play and children's self-concept, stability knowledge, their spatial language, and their math knowledge (research questions 2 and 3).

Research Questions

(1) Are there associations between children's stability knowledge, their spatial language, their math knowledge, interest and self-concept in block play, fluid and crystallized intelligence and working memory?
(2) How frequently do preschool teachers use instructional strategies (i.e., use of language to stimulate communication, sensitivity) in block play and are there associations between their aspects of instructional quality and the use of spatial language, math language and scaffolding?

(3) Are there associations between preschool teachers' instructional quality (overall and specific) and children's stability knowledge, spatial language, mathematical knowledge, interest and academic self-concept?

Methods

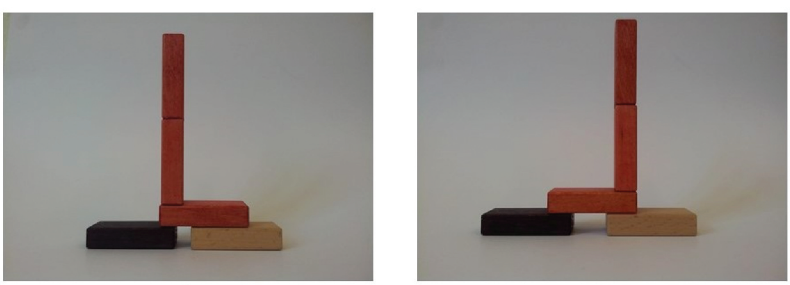
The research was conducted from January to July 2022. The sample consisted of $N = 431$ children (207 boys and 224 girls; $M = 71.31$ months, $SD = 7.67$, $Min = 52$, $Max = 91$) and $N = 73$ preschool teachers. Prior to the start of the study, 80 kindergartens in the surrounding area (±50 km) were contacted and informed about the project. A total of 40 kindergartens consented to participating in the research and assisted in establishing contact with the children and their parents. In Germany, data on ethnicity is typically assessed by asking children what language they speak at home. $N = 353$ children reported German as their mother tongue and $N = 78$ children as their second language. The preschools were situated either in small villages (< 5.000 habitants, $n = 9$), a medium-sized city (<50.000 habitants, $n = 13$) or a large city (>100.000 habitants, $n = 18$). Some children had missing values on some of the items e.g., since they expressed dissatisfaction during testing or fell ill. Therefore, the number of participants varies depending on the analyses. All children participated voluntarily in the study and with their parent's written consent. In advance, the study was approved by the local Ethics Committee.

Instruments

The assessment took about 60 minutes per child and was conducted as single interviews on a tablet computer. The assessment of children's knowledge took place before the video was taken. First, the experimenter established a good relationship with the child by asking about his or her interests in general. Breaks were taken frequently during the assessment, either when the child was tired or if loosing attention.

Knowledge of Stability

We assessed children's stability knowledge with the 16 items Center-of-Mass-Test (COM-Test; [A. M. [Author] & [Author], 2020). Children had to decide whether an asymmetrical construction of building blocks would remain stable (8 items) or fall over (8 items) when a black block was removed (see Figure 2). To reply the items correctly, children had to consider an object's center of mass. Please note that the probability to solve an item by chance is 50%, which might impair internal consistencies. Internal consistency was for stable items $\alpha_{stable} = .65$; and for unstable items $\alpha_{unstable} = .60$.



a b

Figure 2. Example items of the COM-Test (A: unstable, B: stable).

Interest in Block Play

We assessed children's interest in block play via seven picture-based items (A. M. [Author] & [Author], 2020). The children were asked whether they preferred playing with blocks or playing with any other material (e.g., playing with dolls or reading a book). Internal consistency was α = .64.

Self-Concept

Self-concept in block play comprised competence beliefs (12 items, e.g., "how much do you already know about building with blocks") and motivation in block play (9 items, e.g., "show me how much you would like to learn more about building with blocks;" A. M. [Author] & [Author], 2020). Children were shown two identical looking dolls. The interview was framed within a fictional story (e.g., "Kiki already knows a lot about building with blocks. Kora doesn't know so much about building with blocks yet. What about you? Do you already know a lot about building with blocks or do you not know so much about building with blocks?"). In order to reply children had to point on a triangle, which ranged from 1 ("not at all") to 4 ("very much"). Internal consistency was α = .90.

Spatial Language

We assessed children's spatial language with a self-developed test. Based on the categorization system of Cannon et al. (2007). The first task was concerned with "shapes and bodies" and the children were asked to identify a certain shape by pointing (8 items, e.g., "show me the square"). The second task was concerned with "locations and directions." The children had to place a toy figure in a certain way on a game board by considering various aspects of the environment (10 items, e.g., "can you put the figure to the left of the horse?"). The third task was concerned with "spatial properties and dimensions." The children were asked to state the correct response by pointing (8 items, e.g., "can you show me which of these lines are parallel?"). Internal consistency was α = .80.

Mathematical Knowledge

Mathematical knowledge was assessed with the Würzburger Vorschultest (WVT, Endlich et al., 2015). We applied four tasks: *counting* (14 items, e.g., "can you count the candles on the cake?"), *comparison of quantities* (8 items, e.g., "on which side are more biscuits"), *addition and subtraction* (14 items, e.g., "how much is 7 plus 2?") and *word problems in mathematics* (7 items, e.g., "Stefan has 8 biscuits. He has 3 more biscuits than Lisa. How many biscuits does Lisa have?"). Internal consistency was α = .91.

Intelligence and Working Memory

Intelligence was assessed with the German version of the Wechsler Preschool and Primary Scale of Intelligence, Fourth Edition (WPPSI IV; Petermann & Daseking, 2018). We applied three subscales (*matrices* (26 items), α = .88; *vocabulary* (31 items), α = .89; *working memory* (35 items), α = .89). The matrices test served as an indicator for children's fluid intelligence (Cattell, 1987). The vocabulary subscale comprised crystallized intelligence (Cattell, 1987). The working memory subscale was a delayed retrieval test, which asked children to store as many elements as possible. For all three subscales the assessment was ended once the child replied to three consecutive items incorrectly.

Videotaping

To examine preschool teachers' instructional quality in block play we videotaped $N = 73$ interactions between preschool teachers and groups of two to six children each. Every interaction was limited to 30 minutes ($M = 28.48$, $SD = 0.14$). The groups assessed varied in size due to different preschool group sizes, number of children present on the day of data collection or number of filming permissions granted by parents. Preschool teachers were instructed to play with the children with a standardized set of 140 provided building blocks. We applied four subscales of the German version of the *ECERS-R* (Kindergarten Einschätzskala (KES-RZ), Roßbach et al. (2017) and the *Sensitivity and Timing for Instruction Scale*, which was derived from the Erickson Scales (Egeland et al., 1990) as a global rating over the whole videotaped sequence. Moreover, splitting the videos into 10-second-sections, we examine the amount of spatial language following the coding system of Cannon et al. (2007) and mathematical language following Klibanoff et al. (2006) and of cognitive activating scaffolding techniques following M. [Author] et al. (2020). Table 1 shows an overview of the scales examined. Three raters were trained in the category system in a training session lasting several hours. First,

Table 1. Examined variables of preschool teachers' instructional quality in block play.

Category	Scale	Derived from	Range	Explanation
Aspects of Interaction Quality (KES-RZ)	*Stimulate Communication*	*KES-R* (Roßbach et al., 2017)	1 = *inadequate* 3 = *minimal* 5 = *good* 7 = *excellent*	e.g., the teacher rarely/frequently encourages children to communicate. Suggestions for communication are appropriate to the age and abilities of the children.
	General Language Use	*KES-R* (Roßbach et al., 2017)	1 = *inadequate* 3 = *minimal* 5 = *good* 7 = *excellent*	e.g., the teacher talks little/much with the children, asks questions that require longer answers and also has individual conversations.
	Interaction Between Teacher and Child	*KES-R* (Roßbach et al., 2017)	1 = *inadequate* 3 = *minimal* 5 = *good* 7 = *excellent*	e.g., the teacher is inattentive/ attentive in contact with the children, verbal and non-verbal messages are contingent. The teacher enjoys interacting with the children.
	Sensitivity and Timing in Instruction	*Erickson Scales* (Egeland et al., 1990)	1 = *inadequate* 3 = *minimal* 5 = *good* 7 = *excellent*	e.g., teacher consistently provides hints which are well-timed and well-suited to the efforts of the child with appropriate content at appropriate times.
Spatial Language	*Spatial Dimensions*	Cannon et al. (2007)	0-†	e.g., big, small, wide, size, length, height, volume
	Shapes and Bodies	Cannon et al. (2007)	0-†	e.g., circle, square, sphere, cube, pyramid
	Place and Direction	Cannon et al. (2007)	0-†	e.g., towards/away, inside/outside, below, space, distance
	Spatial properties	Cannon et al. (2007)	0-†	e.g., round, curved, even, odd, smooth, circular
Math Language	*Quantities*	Klibanoff et al. (2006)	0-†	e.g., whole/all, part, piece, section, half/third
	Scale units	Klibanoff et al. (2006)	0-†	e.g., centimeter/meter/millimeter
	Mathematical operations	Klibanoff et al. (2006)	0-†	e.g. more/plus, less/minus
Cognitive activating Scaffolding	*Reflecting back children's statements*	Weber and colleagues (2020)	0-†	e.g., you just said that you think the building will not stay/fall
	Encouraging children's further thinking	Weber and colleagues (2020)	0-†	e.g., that was a good idea of yours. Now think even further. What else could happen?
	Activating prior knowledge	Weber and colleagues (2020)	0-†	e.g., have you seen this before?
	Fostering assumptions	Weber and colleagues (2020)	0-†	e.g., what do you think, will it hold or fall?
	Encouraging comparisons	Weber and colleagues (2020)	0-†	e.g., look! What is the difference between X and Y?
	Asking for precise explanations	Weber and colleagues (2020)	0-†	e.g., what have you found out? Why is it stable/unstable?
	Modeling	Weber and colleagues (2020)	0-†	e.g., the building blocks don't always have to lay with the middle on the surface to stay stable. If the heavier side hangs in the air, it is unstable.
	Directing children's attention toward relevant aspects	Weber and colleagues (2020)	0-†	e.g., look at the stone that lies above the red stone. (Accompany the child's gestures).

0-† = indicates the scale range, which is limited to the number of 10-second-blocks per video.

5 videos that were not part of the later analysis were coded independently and then problems and contradictions in the category system were identified, discussed and eliminated. In a next step, all three raters independently coded 20 of the 73 videos analyzed (27.40%). Interrater reliability was measured via Krippendorff's Alpha coefficient and was good with $\alpha_{Krippendorff} = .80$ (Krippendorff, 2004).

Statistical Procedure

For data analysis, we employed the statistical software R, Version 4.2.1 (R Core Team, 2022). We recoded reverse-framed 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) and *dplyr* (Wickham et al., 2022). Effect sizes were determined with the package *lsr* (Navarro, 2015). To address our research questions, we computed correlations using the package *apaTables* (Stanley, 2021). Moreover, we computed a global sum score of preschool teachers' instructional quality by subsuming all subscales from the KES-RZ, sensitivity and use of spatial language, math language and cognitive activating scaffolding.

Results

Descriptive Results

Children's Test Scores

The descriptive statistics of children's test scores are provided in Table 2. Children's knowledge in block play exceeded the mean slightly, however, the difference from the scale mean ($\mu = 8$) was significant ($8.36 > 8$; $t\ (367) = 4.29$, $p \leq .001$). According to J. Cohen (1988) we found a small effect of $d = 0.22$. Interest in block play was rather low, however, self-concept in block play was high. A slight ceiling effect occurred in the spatial language test, nevertheless, there was considerable variance in children's spatial language. The remaining variables were within a medium range.

Intercorrelations of Children's Test Scores

To address the first research question, we computed the correlations of children's test scores (Table 3). Children's stability knowledge, their spatial language mathematical skills and the WPPSI-IV-subscales (fluid, crystallized intelligence and working memory) significantly increased with age. The intercorrelations between fluid intelligence, crystallized intelligence and working memory were positive and thus indicated intelligence-related convergent validity. All three subscales of the WPPSI-IV were associated with children's spatial language and their mathematical achievement. Children's knowledge in block play was associated with their mathematical test score and age, respectively. Boys were more interested in block play than girls and tended to perform better in mathematics than girls. Children who spoke German as their mother tongue tended to be better in the spatial language test, mathematics and crystallized intelligence, respectively, with the latter relying heavily on language skills too.

Preschool teachers' Instructional Quality

The descriptive statistics for preschool teachers' instructional quality in block play are provided in Table 4. Preschool teachers frequently stimulated children's communication, were rather sensitive in their timing and instruction and made use of age-appropriate and child-centered language (Table 4). There was a considerable amount of variance in preschool teachers' spatial language, math language and cognitive activating scaffolding use, on an interindividual (between teachers) and on an intraindividual (between categories) level, respectively (Table 4). Overall, preschool teachers employed spatial language within 19.29% of the 10-second-sections. Math Language (3.03%) and cognitive activating scaffolding (4.65%) were employed quite seldomly.

Table 2. Descriptive statistics for children's test scores.

	Test	*M*	*SD*	*Min*	*Max*	*Scale Range*
Knowledge	Stability Knowledge	8.36	1.60	3	14	0–16
	Spatial Language	19.47	3.58	4	26	0–26
	Mathematical Knowledge	15.66	8.07	3	41	0–43
	Interest	2.48	1.77	0	7	0–7
	Self-Concept	69.85	11.77	21	84	21–84
Cognitive Aspects	Fluid Intelligence	13.01	4.94	0	23	0–26
	Crystal. Intelligence	17.09	6.10	0	27	0–31
	Working Memory	15.52	5.45	1	29	0–35

M = Mean, *SD* = Standard Deviation, *Min* = Minimum, *Max* = Maximum. *Scale Range* indicates the minimum and maximum number of points to be achieved.

Table 3. Correlations of children's test results and demographical data.

	Variable	1	2	3	4	5	6	7	8	9	10
Knowledge	1. Stability Knowledge										
	2. Spatial Language	.02									
	3. Mathematical Knowledge	**.14***	**.50****								
	4. Interest	.10	.08	**.20****							
	5. Self-Concept	−.02	.04	−.04	.02						
Cognitive Aspects	6. Fluid Intelligence	−.02	**.32****	**.44****	−.01	−.00					
	7. Crystal. Intelligence	.02	**.60****	**.45****	.05	−.08	**.43****				
	8. Working Memory	.01	**.23****	**.24****	−.01	−.05	**.37****	**.25****			
Individual Characteristics	9. Age	**.12***	**.22****	**.40****	−.02	−.05	**.32****	**.34****	**.21****		
	10. Language	.03	**.48****	**.16****	.11	.05	.07	**.38****	.08	−.04	
	11. Sex	−.05	.04	**−.17****	**−.56****	−.03	.07	.05	.03	.02	.02

Table 4. Descriptive statistics of preschool teachers' instructional quality in block play.

Scale	*M*	*SD*	*Min*	*Max*	*Scale Range*
Stimulate Communication	6.36	1.01	3	7	1–7
General Language	5.85	1.28	0	7	1–7
Interaction	6.22	1.49	1	7	1–7
Sensitivity	4.32	1.22	1	6	1–7
Spatial Language	33.37	23.08	2	125	0-†
Math Language	5.25	4.92	0	21	0-†
Scaffolding	8.04	7.26	0	45	0-†

General Language = general language use, *Interaction* = interaction between teacher and child. *M* = Mean, *SD* = Standard Deviation, *Min* = Minimum, *Max* = Maximum. *Scale Range* indicates the minimum and maximum number of points to be achieved, *0-†* = indicates the scale range, which is limited to the number of 10-second-blocks per video.

Intercorrelations of Preschool teachers' Instructional Quality Dimensions

To address the second research question, we computed preschool teachers' correlations between dimensions of instructional quality (Table 5). Preschool teachers' cognitive activating scaffolding in block play was significantly associated with the use of spatial and mathematical language and sensitivity and timing in instruction. The latter association can be interpreted as an aspect of convergent validity too. Furthermore, the more teachers stimulated communication, the better scored was their general language use and their sensitivity and timing in instruction. Sensitivity and timing in Instruction, in turn, was associated with all variables.

Associations Between Instructional Quality and Children's Outcomes

To address the third research question, we first examined the relationship between preschool teachers' overall instructional quality in block play and children's stability knowledge in block play, language and math as well as their interest, motivation and self-concept in block play. Since the number of participating teachers per preschool differed, the sum scores were standardized by dividing them through the number of participating teachers per preschool. The results are provided in Table 6.

Table 5. Correlations of preschool teachers' instructional quality in block play.

Variable	1	2	3	4	5	6
1. Stimulate Communication						
2. General Language	**.43****					
3. Interaction	.18	.20				
4. Sensitivity	**.51****	**.38****	**.51****			
5. Spatial Language	.22	.18	**.33****	**.43****		
6. Mathematical Language	.01	.21	**.33****	**.25***	**.63****	
7. Scaffolding	.21	.21	.11	**.31****	**.65****	**.32****

General Language = general language use, *Interaction* = interaction between teacher and child. * indicates $p < .05$. ** indicates $p < .01$.

Table 6. Correlations between children's test scores and preschool teachers' overall instructional quality.

Variable	1	2	3	4	5
Overall Quality	**.18****	.03	−.08	−.04	.07

1 = Stability Knowledge, *2* = Spatial Language, *3* = Mathematical Knowledge, *4* = Interest in Block Play, *5* = Self-Concept (Block Play). * indicates $p < .05$. ** indicates $p < .01$.

Preschool teachers' global instructional quality in block play has shown to be positively correlated with children's stability knowledge.

In order to obtain an in-depth insight into the association between teachers' instructional quality and children's achievement, we determined correlations between particular dimensions of preschool teachers' quality and children's test scores (Table 7). All dimensions of preschool teachers' specific dimensions of instructional quality in block play were associated with the following children's block-play-associated outcomes: knowledge in block play (1), spatial language (2), mathematics (3) and self-concept (5). Spatial and Math Language as well as cognitive activating scaffolding were positively associated with children's knowledge in block play (1). The use of math language and cognitive activating scaffolding had the largest shared variance with children's stability knowledge ($R^2_{MathLanguage} = .03$; $R^2_{Scaffolding} = .03$). To examine the interplay between the significantly correlated variables spatial language, math language and cognitive activating scaffolding and their association with children's stability knowledge, a multiple regression analysis was carried out. The results revealed that only cognitive activating scaffolding remained a significant predictor of children's knowledge when considering all three variables simultaneously ($\beta = .13$, $t\ (352) = 2.28$, $p = .023$). The multiple regression model accounted for 3% of the variance ($R^2 = .03$, $F\ (3,\ 352) = 3.89$, $p = .009$).

Furthermore, preschool teachers' stimulation of communication was positively associated with children's spatial language skills (2). Additionally, preschool teacher's general language use, interaction, sensitivity and timing in instruction as well as math language were positively

Table 7. Correlations between specific dimensions of preschool teachers' instructional quality and children's test scores.

Variable	1	2	3	4	5
Stimulate Communication	.08	**.19****	.07	−.08	.10
General Language	−.03	.02	<.01	.02	**.14***
Interaction	.07	.02	−.01	−.10	**.13***
Sensitivity	.07	.09	−.02	−.10	**.14***
Spatial Language	**.13***	.06	−.03	−.08	.01
Math Language	**.17****	−.09	**−.15***	.05	**.12***
Scaffolding	**.16****	−.02	−.07	.05	.02

General Language = general language use, *Interaction* = interaction between teacher and child. *1* = Stability Knowledge, *2* = Spatial Language, *3* = Mathematical Knowledge, *4* = Interest in Block Play, *5* = Self-Concept (Block Play). * indicates $p < .05$. ** indicates $p < .01$.

associated with children's self-concept (5). Since these four preschool teachers' variables were intercorrelated, we checked for unique effects in a multiple regression on children's motivation. However, the unique effect of none of the predictors contributed significant. The combination of all four preschool teacher variables accounted significantly for 2% of the variance, which was not significant ($R^2 = .02$, F (4, 333) = 1.60, $p = .175$).

Discussion

Instructional quality has been of major interest in educational research and is critical for children's learning achievement (e.g., Y. Guo et al., 2011; Schlesinger & Jentsch, 2016). However, considerable variance in preschool teachers' instructional quality in early science has been shown in a range of studies (e.g., Pianta et al., 2008). Moreover, research has shown that instructional quality is depends on the interplay of teacher and child behaviors (e.g., Scherer & Nilsen, 2016). We examined preschool teachers' instructional quality in block play as an aspect of science teaching and learning on children's achievement by considering children's cognitive and motivational variables. On the backdrop of three research questions, we found that (a) there are positive associations between children's stability knowledge with math knowledge and age, (b) specific aspects of preschool teachers' instructional quality are positively intercorrelated, whereas the association between teachers' cognitive activating scaffolding and spatial language was the strongest and (c) preschool teachers' cognitive activating scaffolding was positively associated with children's stability knowledge when controlling for spatial and math language in a multiple regression model. Furthermore, our results suggest that several aspects of preschool teachers' instructional quality are associated with children's self-concept. Our findings are in line with previous research and provide a deeper insight into a widespread early science learning opportunity such as block play. Our study sheds light on how to support preschool children by examining the association between specific aspects of instructional quality and their association with children's stability knowledge and self-concept.

Children's Achievement and Associated Variables

Firstly, our research indicates that children's stability knowledge is limited as they performed only slightly above the scale mean on the test employed. Therefore, we conclude that most preschool-aged children either show no concept of mass or that they use an object's geometrical center to assess stability. This is in line with previous research on children's stability knowledge which suggests that the majority of children at this age do not yet understand this concept (e.g., A. M. [Author] et al., 2020; Bonawitz et al., 2012; Krist et al., 2018). Moreover, research has shown that children adjust their theories about stability when they are faced with counterevidence to their concept in everyday life, progressively integrating them into their theories, which leads to improved predictions (Bonawitz et al., 2012). In our study, we replicated the evidence of increasing performance with age (Bonawitz et al., 2012; Krist et al., 2018). From this, we may conclude that children in our study might have had the opportunity to engage in block play prior to our examination.

In our research, stability knowledge was positively associated with math knowledge, and age. One math task (*comparison of quantities)* was to estimate the amount of cookies on two images shown at the same time on the left and right side of a separator bar. This task i required the same set of abilities as our stability test, where the children were asked to determine which side of a symmetrical or asymmetrical structure had more blocks, which may have contributed to this correlation.

Spatial language and math knowledge both correlate positively with fluid and crystallized intelligence, working memory and age. The positive correlation of all variables with age can be explained with a maturation effect. Moreover, children's logical reasoning (i.e., fluid intelligence), their vocabulary (i.e., crystallized intelligence) and working memory have shown to be integral parts of mathematical understanding and language capacity in previous studies (e.g., Liao et al., 2015; Schneider & Preckel, 2017). Besides, boys tended to outperform girls in the math test and showed significantly more interest in block play. Interest in block play was positively associated with math knowledge, which, in turn, was positively associated with stability knowledge. This indicates that boys higher math achievement might result from mediation effects between interest on stability knowledge and math knowledge, which, in our correlational design, cannot be tested for. One might hypothesize that boy's higher math achievement is mediated by interest, consequently, they might seek deeper understanding compared to girls (e.g., Renninger & Hidi, 2016).

As expected, children's self-concept in block play was considerably high, which emphasizes children's tendency to overestimate their skills and to engage in all-or-none thinking (e.g., Harter, 2015). Their overly positive self-concept might be explained by the absence of objective feedback until the entrance of primary school (e.g., due to the absence of grades).

Preschool Teachers' Instructional Quality

Preschool teachers' variability of the frequency of spatial and math language and cognitive activating scaffolding use was considerable. They rarely applied spatial language, math language and cognitive activating scaffolding. Few preschool teachers did scaffold children's cognition up to 45 times in the 30 minutes block play episode. However, most of them used cognitive activating scaffolding rarely or hardly at all. With this, we were able to corroborate previous research, which has shown that instructional quality between preschool teachers varies considerably and reflects preschool teachers' difficulty to provide challenging learning support (e.g., Hamre et al., 2014; Klibanoff et al., 2006; Pianta et al., 2008; Spektor-Levy et al., 2013). Spatial and math language were also used rarely. However, spatial language was applied more often than math language. Both, spatial and math language correlate with cognitive activating scaffolding supporting the assumption that they represent an essential aspect of preschool teachers' cognitive activating scaffolding. Thus, in line with other research, cognitive activating scaffolding can be understood as encompassing the use of adequate language to foster children's thinking (e.g., A. M. [Author] et al., 2020; Ferrara et al., 2011).

Overall, preschool teachers' general use of language could be classified as age-appropriate according to the KES-RZ-scale (Roßbach et al., 2017). Further, preschool teachers' stimulation of communication and their verbal and nonverbal contingency to children's reactions were classified as high (sensitivity and timing in instruction scale, Egeland et al., 1990). Preschool teachers' suggestions were well-timed and well-suited to children's efforts and predominantly delivered at appropriate times (e.g., Egeland et al., 1990). Cognitive activating scaffolding was positively associated with sensitivity and timing in instruction, which underpins the educational research hypothesis, that adequate cognitive activating scaffolding is context-specific and at its best contingent to the child's efforts (e.g., van de Pol et al., 2010). Research has shown that preschool teachers' adaptive support is crucial to foster children's learning, albeit teachers seem to have difficulties in the adaption to learning situations (e.g., Siraj-Blatchford et al., 2002).

Interplay Between Teachers' Instructional Quality and Children's Achievement

There is evidence that children's achievement in stability knowledge is associated with playful interactions embracing cognitive activating scaffolding (Casey et al., 2008). To examine the association between preschool teachers' instructional quality on children's stability knowledge, interest, and self-concept in block play as well as spatial language and math knowledge, a general score of instructional quality was computed. We revealed a rather small but significant association between overall instructional quality and children's stability knowledge. This is in line with Weiland et al. (2013), who found small to zero or curvilinear associations between instructional quality and children's outcomes. A possible reason for this might be that preschool teachers' daily routine in kindergarten seldomly allows them to engage in high-quality interactions with a small group of children (Cabell et al., 2013; von Suchodoletz et al., 2014). Thus, one explanation for the small but significant association of overall instructional quality on children's stability knowledge might be explained through the study design which relied on small group interactions of teacher and children. However, the small association might be also explained through former findings which have shown that preschool teachers' knowledge in early science education is limited (Garbett, 2003; Kallery & Psillos, 2001; Yıldırım, 2021). Therefore, we might conclude that children's early science knowledge in block play is not fostered exhaustively. Moreover, children's knowledge was assessed prior to the block-play-interaction. Even though a small number of teachers' instructional quality might have been high, children's knowledge in block play could have been limited due to a restricted block-play experience in kindergarten before the stability test. Another reason for the small association between instructional quality and children's knowledge might be that stability knowledge was a dichotomous variable, which led to a major loss of information and variance. Hence, a dependent variable going into more detail about children's theories (e.g., asking children about their thinking when assessing stability) might reveal more about the relationship between children's knowledge and preschool teachers' instructional quality. Nevertheless, the positive association between preschool teachers' instructional quality and children's stability knowledge was significant and indicates that teacher behavior is linked to child-related outcomes.

However, the overall quality score might have been too general due to the multifaceted and inconsistent nature of instructional quality (e.g., Senden et al., 2022). Thus, we explored the dimensions of instructional quality in block play in more detail. We found significant associations between spatial language, math language as well as cognitive activating scaffolding and children's stability knowledge. However, cognitive activating scaffolding has shown to be the only significant predictor when simultaneously controlling for spatial and math language. Thus, our results expand on the findings of Ferrara et al. (2011) and Casey et al. (2008) and show that cognitive activating scaffolding is a more powerful predictor for children's stability knowledge than spatial and math language. Yet, indicated by our findings, spatial and math language might be understood as aspects of cognitive activating scaffolding. Nonetheless, regarding other early science domains, such as floating and sinking, no effect of cognitive activating scaffolding could be shown on preschool children's achievement, whereas domain-specific language had shown to be the only predictor (e.g., M. [Author] & Saalbach, 2014). Still, floating and sinking is a multifaceted science concept encompassing an object's buoyancy, density and displacement, while stability knowledge can be seen as one specific and focused aspect of block play. Thus, the analysis of the interplay of teachers' cognitive activating scaffolding and children's achievement in a focused context might be more informative than in a broad, multifaceted context. In a broad context, less knowledge might be gained about the association between preschool teachers' specific learning support and children's knowledge. Thus, it might be valuable to examine the influence of cognitive activating scaffolding on carefully selected and narrowly defined contents, due to its high adaptive and context-specific demands in teaching and learning.

We found initial evidence of a substantial role of teachers' sensitivity for children's self-concept. This is in line with evidence of providing responsive and child-contingent feedback as an essential part of effective preschool teaching (e.g., Birch & Ladd, 1997; Downer et al., 2010) and its contribution to fostering children's joy and motivation (e.g., Lepper et al., 2005). We assume two reasons for this finding: First, the sensitivity scale assessed whether teachers' support was contingent in time to the child's effort. We suppose that teachers' well-timed verbal support was more motivating for children than their stimulation of communication and general language use. Teachers' well-timed support might be understood as an aspect of cognitive activating scaffolding too. Second, the sensitivity rating also assessed whether preschool teachers supported appropriately. Thus, the interplay between well-timed and appropriate verbal support might explain the positive association between teachers' sensitivity and children's self-concept, including motivation.

Moreover, our research shows preschool teachers' use of communication to be positively associated with children's spatial language skills and further, the amount of math talk seems to be negatively associated with children's mathematical knowledge. The first result underpins the finding that reciprocal communication between teachers and children is positively associated with children's vocabulary (e.g., Y. Guo et al., 2011). Future research might investigate the negative association between math talk and mathematical skills in more detail. In contrast to Klibanoff et al. (2006) we assessed math talk quite narrowly and separate from spatial language (i.e., shape names were not considered as math talk, which was the case in the work of Klibanoff et al. (2006) and might have contributed to this result). This assumption is underpinned by the finding that children's spatial language was positively associated with their math knowledge. Further, preschool teachers did not use *scale units* (e.g., centimeter, meter) at all, which, might have led to an underestimation of the association between teachers' math talk and children's math knowledge in our study.

Nevertheless, one might keep in mind that instructional quality is not only determined by preschool teachers' behavior. Studies have shown that instructional quality is strongly influenced by teachers' motivational aspects and learning beliefs (e.g., Buehl & Beck, 2015; Scherer & Nilsen, 2016). Thus, teachers' motivation should be assessed in a further study. In our study, we found significant correlations between children's knowledge and teachers' scaffolding and between children's self-concept and teachers' sensitivity. Embedding instructional quality in a reciprocal conjunction of teacher and child behaviors, high instructional quality can be understood as determined by teachers as well as children. Two complementary explanations can be put forward for this: On the one hand, if children were eager to engage in block building activities, teachers were more cognitively activating and more sensitive in their teaching, resulting in higher adaptivity of their support toward children's efforts. On the other hand, more adaptive teacher behaviors may in turn have led to higher self-concepts and cognitive achievement among children. Thus, our study implies the bidirectional aspect of instructional quality in preschool.

Limitations and Conclusion

It should be mentioned that our study, regarding the design, only allows for correlative inferences. We chose this design in order to provide an initial step for a better understanding of preschool teachers' instructional behavior in block play and its possible associations with children's outcomes. Besides, our correlational approach allowed us to observe bidirectional relations between teacher and child behaviors. This is particularly important as research has shown that instructional quality arises from the interplay between teachers and children (Scherer & Nilsen, 2016). We provide an overview of variables involved in block play which might serve as a starting point for future research aiming to detect causal links between preschool teachers' instructional quality and child-related outcomes.

Moreover, some variables that have not been considered in our study might have affected children's learning outcomes (e.g., cognitive capacity, socioeconomic background, presence at preschool) and preschool teachers' instructional quality (e.g., staffing, pedagogical content knowledge, pedagogical beliefs) resulting in a potential underestimation of the actual associations. We primarily concentrated on the cognitive development of children. Equally important aspects in block play, such as social and emotional development (e.g., Rogers, 1985), might be integrated in future research with a broader range of variables to obtain more information on their particular effects.

In conclusion, our study bears two important findings: First, we showed that there is a domain-specific association between preschool teachers' cognitive activating scaffolding and children's stability knowledge. Second, we revealed an association between preschool teachers' sensitivity and timing in instruction and children's self-concept. Moreover, our study shows that it is valuable to examine particular topics in early science, as associations between teacher knowledge and children outcomes might become evident not on a global but on a small-scale level. Based on our study, we have shown the importance of preschool teachers' early science teaching skills to provide children with high quality learning opportunities.

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Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

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