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# How the home learning environment contributes to children's early science knowledge—Associations with parental characteristics and science-related activities

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ABSTRACT

Parents play a pivotal role in introducing their children to science, but little is known about the nature of an early science-related home learning environment. This study examines different aspects of the home learning environment and their associations with children's science knowledge. Mediation analyses of a sample of 257 five-year-old preschool children and their parents show that (1) parental engagement in science-related learning activities with their children is associated with children's science knowledge, (2) structural family characteristics as well as parental interest in science are associated with the frequency of these activities, and (3) associations of structural family characteristics and parental interest in science with children's knowledge are mediated by science-related activities. The results emphasize the important role of parents in children's early science education.



## 1. Early science education

Young children's learning about science has become widely recognized as a core aspect of early education. In many countries, early science education is a central component of preschool curricula (Fleer, Gomes, & March, 2014; Hammer & He, 2015; Kinzie, Whittaker, McGuire, Lee, & Kilday, 2015; Samarapungavan, Mantzicopoulos, & Patrick, 2008; Steffensky, 2017). The growing attention to early education including early science education results from its positive impact on childrenś cognitive development and its long-term effects on later academic success (Eshach & Fried, 2005; Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010; Morgan, Farkas, Hillemeier, & Maczuga, 2016; Saçkes, Trundle, Bell, & O'Connell, 2011; Sylva et al., 2013). Science education refers to the internationally recognized educational concept of scientific literacy (OECD, 2016b; Roberts & Bybee, 2014), which is also adopted in early childhood science education (Samarapungavan, Patrick, & Mantzicopoulos, 2011; Trundle & Saçkes, 2015). The goal of scientific literacy is a scientific education, empowering people to deal with an environment shaped by technology and science (DeBoer, 2000). The concept includes aspects of knowledge (terms, central concepts), as well as knowledge about scientific ways of thinking and working, and affective aspects, such as attitudes and interest in scientific topics (OECD, 2016b). The development of scientific literacy is understood as a life-long process, starting in early childhood. Teaching young children about science builds on their disposition to be curious about the world, to inquire, observe, discover science-related issues, and to gain various experiences with the living (e.g., animals, plants) and the non-living world (e.g., weather, magnetism, or materials) in everyday life (Eshach, 2006; French, 2004; Trundle, 2015). Science knowledge and ideas of young children are often characterized by the description of connections such as "if the sun shines the snowmen melts" than by explanations in a more scientific way (Anders, Hardy, Pauen, & Steffensky, 2017). They are not always completely adequate from a scientific point of view (e.g., "water disappears when it dries") (Chi, 2005).

Learning opportunities support children to develop a basic knowledge of science concepts and first inquiry skills, which is

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the foundation for subsequent cumulative learning processes. This basic knowledge can be differentiated, enriched, sometimes restructured, and connected to new aspects of knowledge during the further course of education (Anders et al., 2017). In science education, these processes of increasing understanding of a topic are often described as learning progressions (Alonzo & Gotwals, 2012; Smith, Wiser, Anderson, & Krajcik, 2006). Learning progressions refer to the development of content knowledge and inquiry skills (Duschl, Maeng, & Sezen, 2011). There is a considerable amount of literature showing that young children are able to develop some basic knowledge in various specific science content areas (Inagaki & Hatano, 1996; Ross, Gelman, & Rosengren, 2005; Trundle & Saçkes, 2015). For example, children can distinguish between solid and liquid substances (Driver, Squires, Rushworth, & Wood-Robinson, 1994) and they are capable of categorizing objects into their material classes as well as to name and describe their characteristics (Kallery, 2015). Preschoolers also develop first inquiry skills (Samarapungavan et al., 2011), which help them to revise misconceptions when dealing with a science-related topic (Samarapungavan et al., 2008). For instance, at the age of six children can differentiate between hypotheses and evidence (Sodian, Zaitchik, & Carey, 1991). Moreover, different intervention studies underline that children extend their concepts based on everyday experiences in appropriate learning environments given they experience stimulating interactions with adults on age-appropriate contents (Hong & Diamond, 2012; Kallery, 2015; Nayfeld, Brenneman, & Gelman, 2011; Peterson & French, 2008; Samarapungavan et al., 2008). In addition, there is some evidence to suggest that early interest in science predicts participation in later informal learning opportunities related to science (Alexander, Johnson, & Kelley, 2012).

The Home Learning Environment

For young children, the most important learning environment for various educational processes is the family context (Hart & Risley, 1995; Melhuish, 2010). The conceptualization of the home learning environment (HLE) in the present study is situated within the bioecological model of human development (Bronfenbrenner & Morris, 2006) which delineates distal and proximal processes to affect the child's development. Proximal or educational processes refer to interactions between the parent and the child. Based on the bioecological model, distal factors are assumed to affect the child's development indirectly and are mediated by proximal processes, which represent the key position in the concept of HLE (Bronfenbrenner & Morris, 2006). Distal factors refer to structural family characteristics such as home language, education, income, or occupational status, the latter often being used as indicators of socioeconomic status (SES) (Bradley & Corwyn, 2002). In addition, distal factors can also include further personal factors such as parental interest (e.g., in a certain domain), and beliefs (Vasilyeva, Laski, Veraksa, Weber, & Bukhalenkova, 2018). Beliefs include a wide range of different types of beliefs, for example, beliefs about oneself (e.g., self-confidence), about the child's development, the importance of domain-specific education or parents' aspirations regarding their child's academic career, and attitudes towards a certain domain (Hancock & Gallard, 2004; Kluczniok, Lehrl, Kuger, & Rossbach, 2013; Murphy, 1992; Pajares, 1992).

The HLE has a significant influence on childrenś emotional and intellectual growth, school readiness, and their subsequent academic achievement (Sammons et al., 2015; Shonkoff & Phillips, 2000). The fundamental role of the HLE for children's learning is well documented for domains like literacy (Hartas, 2011; Melhuish et al., 2008; Niklas & Schneider, 2013; Weigel, Martin, & Bennett, 2006) and numeracy (Anders et al., 2012; DeFlorio & Beliakoff, 2015; Kluczniok, 2017; Niklas & Schneider, 2014; Zippert & Rittle-Johnson, 2018).

At school-entry children differ greatly in their early math and literacy skills and these differences are predictive of later academic achievement in these domains (Duncan et al., 2007). Recent evidence suggests that similar associations hold for children's early science knowledge as well (Morgan et al., 2016). Moreover, differences in children's early science knowledge are associated with both structural family characteristics and later science performance in school (Morgan et al., 2016). However, there is a paucity of empirical research about the impact of the HLE on childrenś science-related learning. The majority of studies examine the effects of one HLE factor, e.g., either the family's SES or parental beliefs on children's outcomes. Very little is known about how parental beliefs and interest, structural family characteristics, and educational processes play together and how they are associated with childrenś early science-related learning. Therefore, the present study aims to explore the science-related home learning environment by investigating how different HLE factors (i.e., the familyś structural characteristics, parental beliefs and interest, and educational processes) are associated with 5-year-old preschool children's science knowledge.

## 2. The role of the home learning environment in children's science learning

The quality of the HLE is typically characterized by structural family background characteristics, parental beliefs and interest as well as educational processes, which in turn affect the childś development indirectly or directly (Melhuish, 2010; Morgan et al., 2016; Schmerse et al., 2018; Vasilyeva et al., 2018). Educational processes embodied in parent-child interactions constitute the main factor in the conceptualization of the HLE. These processes can be subdivided into general processes (e.g., daily joint activities, emotional support) and domain-specific processes to create opportunities for numeracy, literacy, or science-related learning (Kluczniok et al., 2013). Science-related aspects of the HLE refer to factors with science-related contents including the guidance of children's interests, stimulating curiosity about natural phenomena, and creating opportunities to learn about science and scientific inquiry, such as observing, measuring, and comparing (Alexander et al., 2012; Callanan, Shrager, & Moore, 1995; Crowley et al., 2001a; Shymansky, Yore, & Hand, 2000). These opportunities encompass a wide range of activities such as joint reading of children's science and nature books, performing science experiments (e.g., planting seeds and observing the changes in growth under different conditions of soil, light, water, or temperature), as well as hands-on activities (e.g., collecting and comparing stones, leaves, etc.). Moreover, activities like playing with sand and water or engaging with children in interactions about their observations of natural phenomena (e.g., the sinking of stones and floating of branches on the water) are also considered science-related learning activities (Alexander et al., 2012; Crowley & Galco, 2001). These activities may be spontaneous (e.g., talking about an occurring rainbow) or they may be planned (e.g., an experiment). Some directly link to science (e.g., building a wind-powered car), while others occur more incidental even without parents recognizing them as science learning opportunities (e.g., playing with water and experiencing it as a liquid). All these shared activities provide opportunities for children and parents to talk and learn about science.

Generally, it is assumed that children benefit from the provision of high-quality learning opportunities, access to high-quality learning materials, and a high frequency of stimulating interactions. This, in different domains, there is evidence that higher domain-specific process quality is associated with higher domain-specific outcomes (Anders et al., 2012; Kluczniok, 2017; Sylva et al., 2013). For the domain of science, there is some evidence from the preschool context showing that higher instructional quality in preschool classrooms is contributing to children's science knowledge (Gropen, Kook, Hoisington, & Clark-Chiarelli, 2017), especially for lower SES children (Greenfield et al., 2009). Referring to the impact of the frequency of science-related activities there is first evidence that the frequency spent with science education in preschools forecasted children's self-initiated science activities (Saçkes et al., 2011). For the domains of literacy and numeracy, the frequency of domain-specific learning activities is one important indicator of HLE quality as it is associated with positive outcomes in these domains (Dunst, Simkus, & Hamby, 2012; LeFevre et al., 2009; Niklas & Schneider, 2014). Whether these results can be translated to the domain of science is not clear. Therefore, the present study can help to provide further insights into associations of the frequency of science-related activities between parents and children and children's science knowledge. Generally, quantity alone cannot be completely equated with quality but a useful combination seems to be appropriate (Leseman & van den Boom, 1999). For example, the intervention study by Mantzicopoulos, Patrick, and Samarapungavan (2013) underlines that ongoing opportunities to deal with science topics in preschool and at home with appropriate support and instruction have several benefits including improved science knowledge and higher self-confidence.

Educational processes do not operate in an isolated manner and especially domain-specific processes are associated with structural family characteristics, as well as with parental interest and beliefs for example about the importance of academic preparation (Kluczniok et al., 2013). Findings on the interplay between particular HLE factors predominantly come from the domains of literacy and numeracy documenting that the support of literacy and numeracy skills at home is linked to structural family characteristics. These characteristics are often measured by parental education, the family's financial resources, or the home language but they also covary with interests and beliefs (Anders et al., 2012; DeFlorio & Beliakoff, 2015; Hartas, 2011; Kluczniok, 2017; Niklas & Schneider, 2013). For example, parents of preschool and school children who feel less confident about their mathematical skills tend to offer less support of math-related activities (Skwarchuk, 2009; Vasilyeva et al., 2018). As a result, academic achievement gaps at school entry and during the later school years largely derive from the fact that the degree of numeracy and literacy support at home strongly depends on parental beliefs and interests, and structural family characteristics (Anders et al., 2012; Kent & Pitsia, 2018; LeFevre et al., 2009).

Whether these results translate to the domain of science is not clear. Even less, however, is known about the associations between structural family characteristics, parental interest and beliefs, and their effects on childrenś early science skills. Previous research has primarily focused on students in secondary school and emphasized that parents' beliefs and interest in science appear to be stable over time and presumably shape high school students' perspective towards learning science as well as later science-related career choices (Chen, 2001; Ferry, Fouad, & Smith, 2000; Kaya & Lundeen, 2017). On the other hand, studies indicate that parents are less involved in their children's science learning in elementary and secondary school as compared to, for example, math and reading (Kaya & Lundeen, 2017; Shymansky et al., 2000). The reduced involvement of parents may be due to their own negative science learning experiences, a lack of science skills, beliefs that science is more difficult compared to other subjects, or fewer exchanges with teachers about science-related topics (Kaya & Lundeen, 2017; Lurdes Cardoso, 2002; Shymansky et al., 2000; Solomon, 2003). Moreover, there is some evidence that parents with a weaker interest in science have more negative experiences in their own science learning (Kaya & Lundeen, 2017) and parents with negative attitudes towards science tend to be more likely to avoid science activities at home, although they consider science learning for their children as important (Lurdes Cardoso, 2002; Shymansky et al., 2000). There is some evidence that a similar picture can be observed for parents of preschool children. A study by Silander et al. (2018) found that although the vast majority of parents are aware of the pivotal role they play in their children's learning, many do not feel confident supporting their children's science learning. In this study, only half of the parents felt very confident in supporting their preschool children's science learning compared to 75% who felt very confident in supporting their children's literacy skills. These numbers hold even though parents consider science an important component of education. On the one hand, the lack of confidence may derive from lower science knowledge. On the other hand, parents' insecurity to answer children's science questions in an age-appropriate and comprehensible manner is likely to play a role as well (Silander et al., 2018).

A lack of parental engagement in their children's science learning activities also covaries with parental SES. On average, children from lower SES families experience fewer learning opportunities at home (Bradley & Corwyn, 2002) and in science-related activities such as visiting a museum or a zoo (Bradley, Corwyn, McAdoo, & Coll, 2001; Iruka, Dotterer, & Pungello, 2014). Lower SES parents also report lower confidence in supporting their children's science education and put a greater emphasis on the role of institutions (schools) in supporting children's science learning (Silander et al., 2018). The implication from these studies is that differences in providing materials and learning activities in the HLE including science as well as fewer social and cultural capital related to science contributes to early science achievement gaps (Archer et al., 2012; Bradley et al., 2001; Morgan et al., 2016; Trundle, 2015). Findings from the Early Childhood Longitudinal Study (ECLS, kindergarten to 8th grade) reveal that science achievement gaps related to the SES are already in place before children enter elementary school and persist until middle school (Morgan et al., 2016). Recent results from the Trends in International Mathematics and Science Study (TIMSS) confirm that in many participating countries, fourth-grade students from higher SES families perform significantly better in math and science than students from lower SES families (Martin, Mullis, Foy, & Hooper, 2016). Furthermore, there is emerging evidence that especially families with a higher SES attach greater importance to the science learning of their preschool children (Saçkes, 2014).

Other mediating factors may also play a role. For instance, Zhang, Hu, Ren, and Zhang (2019) showed that children from lower SES families performed poorly in science, inter alia, because they showed difficulties in their vocabulary skills. On average, lower SES parents tend to offer fewer language stimulation and verbally enriched interactions (Fernald, Marchman, & Weisleder, 2013; Pan, Rowe, Singer, & Snow, 2005). Given that home-based language and literacy activities are closely connected to and provide prerequisites for science activities (e.g., asking questions, describing observations, explaining ideas), reduced language and literacy activities do not only affect language skills (Niklas & Schneider, 2013; Senechal & LeFevre, 2002) but also science skills (Blums, Belsky, Grimm, & Chen, 2016). Similar mediating effects of language skills are known from the domain of mathematics (McClelland et al., 2007; Soto-Calvo, Simmons, Willis, & Adams, 2015).

Relatedly, children's home language, as part of the structural family characteristics in the HLE model, is associated with achievement disparities including science (Hoff, 2013; Kähler, Hahn, & Köller, 2020; Morgan et al., 2016; National Academies of Sciences, Engineering, & Medicine, 2017). Dual language learners often receive less support in their academic learning at home (Kluczniok et al., 2013). In addition, there is evidence that differences in majority language skills between dual language learners

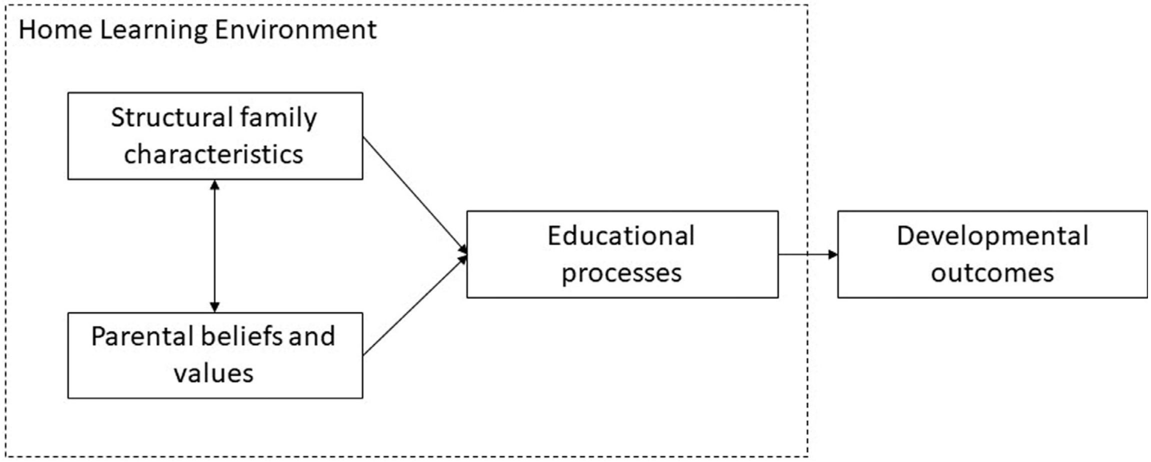


**Fig. 1.** Theoretical model of mediation processes within the home learning environment. (Adapted from Kluczniok et al. (2013))

and their monolingual peers mediate the effects of children's home language background on their science knowledge at age 5 (Hahn & Schöps, 2019) beyond and above co-occurring effects related to SES (Kähler et al., 2020).

Finally, parents may tend to engage in gender-specific ways in science-related activities with their children offering more science learning opportunities to boys than girls (Alexander et al., 2012; Tenenbaum & Leaper, 2003). These gender differences in parents' engagement in science-related activities emerge early (Alexander et al., 2012) and parents of 3- to 5-year-old boys consider science as more important than other academic fields and compared to parents of 3- to 5-year-old girls (Saçkes, 2014). Results regarding gender differences in children's motivation, interest, and achievement in science are mixed (Curran & Kellogg, 2016; Leibham, Alexander, & Johnson, 2013; Oppermann, Brunner, Eccles, & Anders, 2018). However, given the differences in interest and to some extent in achievements of older students in science, it seems appropriate to consider gender in the context of sciences (DeWitt et al., 2011; Martin et al., 2016; OECD, 2016a). Based on the findings reviewed above, it seems plausible to assume that structural family characteristics, parental interests and beliefs are likely to contribute to explaining individual differences in the frequency of parental science-related activities with preschool-aged children (Fig. 1). Specifically, science-related educational processes in the family are hypothesized to be directly related to childrenś developmental status, and at the same time to depend on parental interests and beliefs as well as structural family characteristics. Consequently, effects of parental interest and beliefs in and about science as well as structural family characteristics are assumed to be related indirectly to children's development and to be mediated by the extent of educational processes (Biedinger, 2011; Melhuish et al., 2008).

## 3. The present study

Taken together, there is considerable evidence on the important role of parents' involvement in young childrenś learning. Furthermore, there is evidence that science-related achievement gaps are already in place at school entry. However, there are only very few empirical studies examining the science-related educational processes within the family during the preschool period. Currently, very little is known about the associations between parental involvement in science-related educational processes and childrenś science knowledge before school entry. It remains unclear whether structural family characteristics and parental interest and beliefs are associated with the frequency of parents' engagement and to what extent the degree of this engagement mediates effects of structural family characteristics and parental interest and beliefs on children's science knowledge at this early stage. Thus far, no study has simultaneously considered the interplay of different HLE factors and their associations with young children's science knowledge. Therefore, in the present study, we investigated whether parental engagement in science-related learning activities provides a mechanism through which structural family characteristics and parental interests and beliefs are indirectly associated with 5-year-old preschool children's knowledge about science.

The main hypothesis of the current study was that educational processes within the family hold the central position in the HLE and mediate associations of structural family characteristics as well as parental interest and beliefs with children's knowledge. Based on the results from previous research, we expected that (1) parents with a higher educational level and German home language engage more frequently in science-related activities with their children, (2) parents who hold stronger beliefs about the importance of early science education and with a higher personal interest in science offer more science-related activities at home (controlling for education and home language), and (3) the frequency of parental learning engagement mediates these associations with children's knowledge about science.

## 4. Method

### 4.1. Participants

The sample consisted of $N = 257$ 5-year-old children ($M = 5.5$ years, $SD = 4$ months, 48% girls) and their parents who participated in the study (Steffensky, Lankes, Carstensen, & Nölke, 2012). The study was based on a random sample and was conducted in the municipal area of a medium-sized city in Western Germany. The participants were recruited from 13 different, publicly funded preschools. Note that in Germany, children typically attend preschool between the age of 3 and 6 years before they enter formal schooling by the age of 6 or 7 years. The majority (84%) of the children in our study entered preschool at the age of 3 and most children (52.4%) attended preschool for at least 3-4 hours a day, followed by 33.6% of children who spent at least 5-6 hours a day in preschool.

Parents gave their written permission to participate in the study. Parents completed a paper-pencil questionnaire containing questions about structural family characteristics (i.e., home language, parental education), parental beliefs about science education in preschool, and parental interest in science. The questionnaires were primary (79%) completed by the mother, stepmother, or female legal guardian. With respect to parental education, 57% reported a university degree, 38% vocational training degree, and 5% lower secondary school degree without vocational training as their highest level of education. Among families, 12% of parents reported speaking a home language other than German.

### 4.2. Procedure

Information on structural family characteristics, parents' interest in science as well as their beliefs about preschool science education and science-related activities within the family were collected via paper-pencil questionnaires in September and October 2009. Children's cognitive abilities and science knowledge were assessed in September and October 2009 (beginning of the preschool year). All tests were performed by 22 research assistants. Before the test administration, all research assistants were trained in a 6-hour training session. Training included an introduction to the tests and exercises in how to administer the tests properly and in a standardized manner.

Each child was tested by one research assistant individually in a quiet room in their preschool. Testing of children's science knowledge was administered via a structured interview, which was audiotaped by research assistants. During children's science test, the research assistant asked the child different questions, i.e., forced-choice, multiple-choice, open-ended, and ordering questions, which refer to scientific content ($n = 24$) as well as scientific process knowledge ($n = 5$). Children did not receive guidance during the test, in case of wrong answers the question was not repeated. If a child did not know the answer, it was made clear that this was not important and that it was a really difficult question to answer, but no hints were given. There were no time constraints. The average time spent to complete the 29 items was 23 minutes.

Parents gave written consent for children's participation. It was clear to every child that she/he could leave the test at any time without any penalty. The test was completed by 97% of the children. Children's responses were coded live. In addition, the interviews were audiotaped for checking purposes and to ensure reliable coding of open-ended questions. Research assistants were able to code open-ended questions immediately or they noted the child's answer and coded the answer later on the same day. An additional coding of open-ended questions was conducted by a second trained rater. Agreement between raters was 97%.

## 5. Measures

### 5.1. Outcome

*Science knowledge*. Children's science knowledge was assessed using a test instrument developed by Carstensen, Lankes, & Steffensky, 2011. The test contained 29 items covering scientific content knowledge ($n = 24$) as well as scientific process knowledge ($n = 5$). Content knowledge and process knowledge are regarded as central components of science knowledge (Kinzie et al., 2015). The science content knowledge items included the melting and freezing of water and ice (11 items), the evaporation and condensation of water (8 items), as well as solution and non-solution in water (5 items). The items were developed to measure relevant terms and first conceptual knowledge (e.g., the snowman is melting because the sun shines) in the described content areas. The science domains have been chosen because they are part of most of the preschool curricula in Germany and are central concepts in science (Steffensky, Lankes, Carstensen, & Nölke, 2012). Moreover, children gain various experiences with water in daily life (Carstensen, Lankes, & Steffensky, 2011). Items were developed based on preschool children's spontaneous explanations and ideas derived from pilot interview data. We used formulations in child-appropriate language. The process knowledge items included observing, measuring, and comparing. Sample items are given in Appendix 1.

The test items required different response formats including forced-choice, multiple-choice, open-ended, and ordering. Almost all items were picture-based representing the central element of the item (e.g., frozen puddle, ice cube, boiling water, steam). Correct responses received 2 points and incorrect responses 0 points. For some test items, there was an additional middle category which received 1 point. This middle category covered children's circumscriptions of relationships or concepts, e.g., circumscribing the term *melting* with *running* or *becoming liquid*. A detailed description of the test including validity measures and details on IRT modeling is given in (Carstensen, Lankes, & Steffensky, 2011). The reliability of the test was good (WLE reliability = 0.75). Testing for unidimensionality revealed evidence for a one-dimensional construct. Overall, there was no indication of a severe item over- or underfit. The correlations of the item scores with the total score varied between 0.22 and 0.51 with an average correlation of 0.37. Convergent validity was substantiated by positive correlations ($r = 0.49$) of the total score with a standardized test of general cognitive abilities (Cattell et al., 1997). An additional study showed that preschool children scored lower compared with first graders, controlling for general cognitive abilities (0.98 logits, $t = -7.16$, $P < 0.001$). This result is in accordance with the expectation that older children have more formal and informal learning opportunities and therefore score higher in the test. Accordingly, these data provide evidence of the validity of the test and its interpretation (Steffensky, Lankes, Carstensen, & Nölke, 2012).

### 5.2. Home learning environment

*Structural family characteristics.* Data on the structural family characteristics included home language (German vs. non-German) and parental education. Parental highest educational degree and highest vocational training degree were classified according to the International Standard Classification of Education (ISCED; OECD, 1999).

*Parental beliefs about science education in preschool.* Parents were asked about their opinion regarding the educational value of science education in preschool. Parents rated on a four-point scale (0 = *not important*, 3 = *very important*) the importance of acquiring scientific content knowledge in preschool classrooms as well as preparing children for elementary school regarding scientific literacy. The scale consists of four items (Cronbach's $\alpha = 0.79$).

*Parental interest in science*. Parents rated on a four-point scale (0 = *strongly disagree*, 3 = *strongly agree*) their personal interest in science. The five items of this scale covered enjoying reading and learning about science as well as occupying oneself with science-related matters (Cronbach's $\alpha = 0.92$). Parents' interest in science was collected via questionnaire from the Pisa Study 2006 (Frey et al., 2009).

*Science-related activities.* The scale included five items on the frequency of science-related activities between parents and children as well as a joint usage of science-related materials (e.g., joint reading of children's science and nature books or engaging with children in conversations about their observations of nature). The four-point scale (0 = *never*, 3 = *at least once per week*) showed satisfactory internal consistency (Cronbach's $\alpha = 0.76$). Further information (e.g., standard deviation, range, missing data) regarding parental beliefs and science-related activities are given in Table 1. Sample items are given in Appendix 2.

**Table 1**
Correlations and descriptive statistics for study variables.

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | *M* | *SD* | range | *n* | % missing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Science knowledge | | | | | | | | −0.11 | 0.98 | −4.22-2.36 | 253 | 1.6 |
| 2. Gender | 0.02 | | | | | | | | | | 257 | 0 |
| 3. Cognitive abilities | 0.33*** | −0.08 | | | | | | 5.96 | 2.61 | 0-12 | 257 | 0 |
| 4. Parental education | 0.24*** | −0.08 | 0.13 | | | | | 4.63 | 1.33 | 1-6 | 222 | 13.6 |
| 5. Home language | −0.23** | 0.09 | −0.15* | −0.33*** | | | | | | | 224 | 12.8 |
| 6. Science in preschool | −0.16* | 0.05 | −0.14* | −0.24*** | 0.11 | | | 2.32 | 0.58 | 0.25-3.00 | 223 | 13.2 |
| 7. Parental interest in science | 0.18** | −0.06 | 0.12 | 0.36*** | −0.17* | 0.03 | | 1.87 | 0.73 | 0.20-3.00 | 221 | 14.0 |
| 8. Science-related activities | 0.27*** | 0.01 | 0.08 | 0.41*** | −0.44*** | 0.00 | 0.54*** | 2.01 | 0.63 | 0.00-3.00 | 224 | 12.8 |

*Notes*: Ranges represent actual range values. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

### 5.3. Covariates

The child's gender and cognitive abilities were included as covariates to control for individual differences explained by these factors that were relevant to the construct under study. Children's cognitive abilities were assessed in September and October 2009 using the nonverbal analogies subtest of the German version of the Culture Fair Intelligence Test (CFT-1). The CFT-1 determines the basic intelligence, e.g., the child's ability to identify rules and patterns, of children between the age of 5 and 9. It is appropriate for preschool, elementary school, or schools for special education. By providing nonverbal tasks, the test is suitable for children with a non-German home language and children with linguistic difficulties. The CFT-1 comprises 5 subtests (substitutions, labyrinths, classifications, analogies, and matrices). The analogies subtest used in our study consists of 12 tasks and allows to assess children's ability to identify features and to recognize and generalize rules in pictorial stimuli. In detail, the child needs to mark the illustration in a series of 5, which is equal to the given illustration. The test provides information about children's ability to grasp and solve nonverbal problems. The test shows acceptable reliability (Cronbach's $\alpha = 0.72$) (Cattell et al., 1997).

### 5.4. Statistical analysis

Statistical modeling of children's competence was performed using the ordered partition model (Wilson, 1992). This version of the Rasch model allows for equal weighing of dichotomous and multi-nominal response formats. It generalizes the partial credit model (Masters, 1982) for more than two response categories to cases in which not all categories are observed in all items. We used the person parameter as the dependent variable in the subsequent analyses (Carstensen, Lankes, & Steffensky, 2011). In the next step, we tested the assumption that structural characteristics of the family and parental interest and beliefs reveal indirect effects on children's knowledge mediated by science-related activities between parents and children. In order to test this assumption, we specified a path model represented in Fig. 2. The model was specified such that structural family characteristics (parental education, home language), parental beliefs about science in preschool as well as their interest in science, and child covariates (gender, cognitive abilities, represented in Fig. 2) served as predictors of the mediator variable (science-related activities) as well as predictors of the outcome variable (scientific knowledge). In addition, the mediator served as a predictor of the outcome variable. Direct effects are represented by paths from the predictors to the outcome. Indirect effects are the product of the paths from the predictors to the mediator and the path from the mediator to the outcome variable. The model was specified in M*plus* (Version, 7.4, Muthén & Muthén, 1998-2012).

Missing data occurred to a limited degree in our sample ranging from 0 to 14 percent across variables (see Table 1 for details). We used full information maximum likelihood (FIML) estimation to handle missing data. FIML estimation uses the complete observed information matrix (including covariates) to compute the standard errors for the parameter estimates thereby rendering possible biases less likely. Following, we used bootstrapping ($n = 5000$) to estimate effects and to obtain confidence intervals (Preacher & Hayes, 2008).

## 6. Results

Descriptive statistics and correlations for all variables are presented in Table 1. Children's science knowledge test performance was positively correlated with their cognitive abilities ($r = 0.33$, $P < 0.001$), parental education ($r = 0.24$, $P < 0.001$), parental interest in science ($r = 0.18$, $P = 0.002$), and the frequency of scientific-related activities ($r = 0.27$, $P < 0.001$). Children's science knowledge correlated negatively with a non-German home language ($r = -0.23$, $P < 0.001$) and parents' rating of the importance of science education in preschool

($r = -0.16$, $P < 0.01$). In addition, parental science-related activities were positively correlated with parental education ($r = 0.41$, $P < 0.001$) as well as parents' interest in science ($r = 0.54$, $P < 0.001$) and negatively correlated with a non-German home language ($r = -0.44$, $P < 0.001$).

### 6.1. Path analyses

We implemented a path model as outlined above (Fig. 2). The model was saturated (zero degrees of freedom) and thus did not allow assessments of model fit. The $R^2$ values for the endogenous variables in the model were 20% for scientific knowledge and 45% for science-related activities. Within the model, cognitive abilities ($\beta = 0.28$, $SE = 0.06$, 95% CI [0.152, 0.399], $P < 0.001$) and science-related activities ($\beta = 0.18$, $SE = 0.08$, 95% CI [0.016, 0.315], $P = 0.028$) were significantly associated with children's test performance. There were no other significant direct effects on children's science knowledge. Science-related activities as the mediator variable was associated with parental education ($\beta = 0.16$, $SE = 0.06$, 95% CI [0.008, 0 0.292], $P = 0.027$), home language ($\beta = -0.32$, $SE = 0.05$, 95% CI [−0.462, −0.173], $P < 0.001$) and parents' interest in science ($\beta = 0.43$, $SE = 0.05$, 95% CI [0.336, 0582], $P < 0.001$).

The primary hypothesis of the current study was that educational processes within the family mediate the associations between structural family characteristics as well as parental beliefs and interest and children's developmental outcomes. We, therefore, tested the indirect effects of parental education, home language, beliefs about preschool science education, and parents' interest in science on children's scientific knowledge through science-related activities as the mediator. To quantify effect sizes, we report the completely standardized indirect effects (Preacher & Kelley, 2011) with bootstrapped 95% confidence intervals. The results of the indirect effects are presented in Table 2. There were significant indirect effects of home language ($\beta = -0.06$, $SE = 0.028$, 95% CI [−0.127, −0.010], $P = 0.041$) and parental interest in science

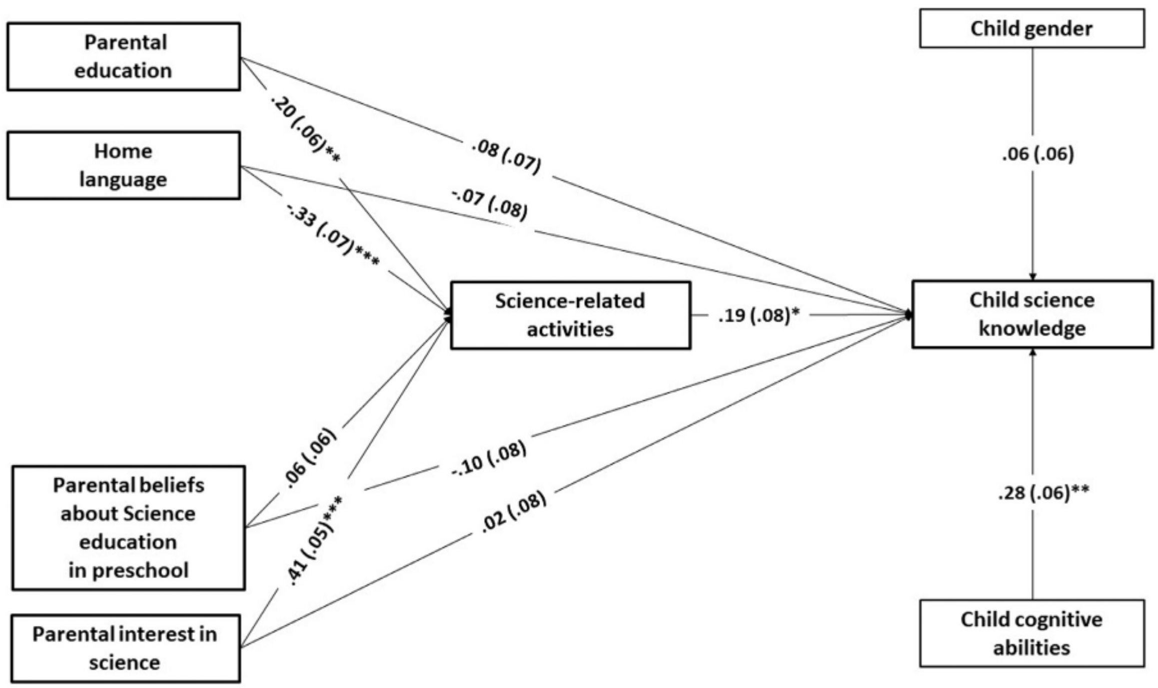


**Fig. 2.** Mediation model with standardized path coefficients and standard errors in parentheses.
*Notes:* The model includes cognitive abilities and gender as covariates $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

**Table 2**
Standardized estimates for indirect effects on children's science knowledge.

| | Est. | *SE* | *P* | 95% CI | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| Cognitive abilities → SRA | −0.01 | 0.011 | 0.638 | −0.035 | 0.011 |
| Parental education → SRA | 0.03 | 0.020 | 0.090 | 0.002 | 0.078 |
| Home language → SRA | −0.06 | 0.028 | 0.041 | −0.127 | −0.010 |
| Science education in preschool → SRA | 0.01 | 0.010 | 0.472 | −0.009 | 0.034 |
| Parental interest in science → SRA | 0.08 | 0.037 | 0.035 | 0.010 | 0.160 |

Est. = standardized estimates; CI = confidence interval; SRA = science-related activities.

($\beta = 0.08$, $SE = 0.037$, 95% CI [0.010, 0.160], $P = 0.037$) on children's outcomes. The mediated pathway of parental education just failed to reach significance level ($\beta = 0.03$, $SE = 0.020$, 95% CI [0.002, 0.078], $P = 0.090$). Results indicated no further indirect effects. Thus, in line with our main hypothesis, educational processes within the family mediated the associations of structural family characteristics as well as parental interest in science with children's science knowledge.

## 7. Discussion

The present study investigated the associations of a science-related HLE with 5-year-old preschool children's science knowledge using a mediation modeling framework. In sum, there were 3 main findings. First, there was an association of parental engagement in science-related learning activities with children's science knowledge. Second, structural family characteristics (home language, parental education), as well as parental interest in science were associated with the frequency of parents' science-related activities with their children. Third, associations of the structural family characteristics and parental interest with children's knowledge were mediated by the frequency of science-related activities controlling for the child's gender and cognitive abilities. The results support the main hypothesis of the current study. Educational processes within the family represent the central position in the HLE and mediate associations of structural family characteristics as well as parental interest in science with children's knowledge. This result converges with previous findings from other domains of learning, which support the assumption that domain-specific processes are strongly related to structural family characteristics and parental beliefs and interest in specific domains (Bingham, 2007; DeFlorio & Beliakoff, 2015; Vasilyeva et al., 2018).

In detail, we expected that parents with a higher educational level and a German home language engage more frequently in science-related activities with their children. Our results indicated that parental support of children's early science knowledge was positively correlated with parental education and negatively correlated with a non-German home language (even when controlling for parental education). This complements the small number of previous findings addressing preschool children's science knowledge that show differences in the science achievement of children from higher and lower SES families (Morgan et al., 2016; Saçkes, 2014; Zhang et al., 2019) and children from majority and minority language homes (Hahn & Schöps, 2019; Kähler et al., 2020). Our findings indicate that parental support of childrenś science knowledge mediated associations of a non-German home language with children's science knowledge. This finding adds to existing research reporting associations between children's science knowledge and the family's home language (Kähler et al., 2020; Morgan et al., 2016). In addition to mediational processes through language skills (Hahn & Schöps, 2019; Zhang et al., 2019), this finding points to possible cultural differences in supporting the science-learning of children from minority language homes. Similar results have been reported for other academic domains (Anders, Grosse, Rossbach, Ebert, & Weinert, 2013; Hartas, 2011; Kluczniok, 2017; Niklas & Schneider, 2013).

Our data suggest that higher SES families offer more opportunities to learn about science. This might be due to the fact that children from higher SES families have easier access to science-related learning materials such as books about science or activities such as visiting museums, science centers, or even different types of landscapes where children can make broad experiences with plants and animals (Bradley et al., 2001). Besides differences in science-related activities in the HLE, there is evidence that SES differences also contribute to other internal factors such as literacy, executive function, and self-regulation skills which in turn influence science (or other domain-specific) achievement (Anthony & Ogg, 2019; Blums et al., 2016). Although our results suggest that part of the relationship between parental SES and achievement is mediated by differences in science relevant activities in HLE, it can be assumed that the relationship between SES and achievement is due to a more complex interaction with other mediating factors.

However, there is also evidence suggesting that measures of SES including parental education are only moderately associated with the HLE (Melhuish et al., 2008) indicating considerable variance in HLE quality across income and educational levels. In the current study, associations between educational levels and science-related HLE tended to be somewhat larger ($r$ = 0.44) than those reported for more global measures of HLE ($r$ = 0.28-0.32; Melhuish et al., 2008). Although sample compositions tend to differ slightly between studies, this pattern of results might also indicate that besides educational resources and cultural and social capital, parent's interest and knowledge reveal a greater impact on promoting children's science skills than numeracy or literacy skills (Archer et al., 2012). Thus, it might be assumed that parents with higher educational backgrounds had more science-related learning opportunities themselves and therefore might possess a better understanding of phenomena making them aware of possibilities to engage in science-related activities (Funk & Goo, 2015). Science understanding, for instance, can be assumed as a prerequisite to recognizing a phenomenon in everyday life (e.g., steam over a kettle) and to talk about it. Furthermore, higher educated parents may feel more prepared to answer their childrenś questions regarding natural phenomena. This may be challenging for parents with lower educational backgrounds. For example, in the school context, the study of Zady and Portes (2001) found that lower educated mothers were willing to help their 7th-grade children with their science homework, but had difficulties in understanding the tasks. In turn, parents with lower educational backgrounds presumably had fewer opportunities to learn about science. They might feel less prepared to engage in science-related activities with their children or are less aware of science in everyday life. This might be different in typical informal learning activities for young children in other domains of learning, such as numeracy. For example, counting stair steps or the dots on a dice, or discussing which building block tower is taller are typical math relevant activities which do not require a deeper content knowledge.

Although structural family characteristics, including parental education and home language, play an important role, there are additional factors involved in explaining individual differences in science-related educational processes, even when controlling for structural family characteristics. Specifically, we expected that parents who hold stronger beliefs about the importance of preschool science education and parents with a higher personal interest in science offer more science-related activities at home (controlling for structural family characteristics). Indeed, our results revealed that engagement in science-related activities was positively associated with parents' interest in science, but not, however, with their beliefs about the importance of science education in preschool. For the domain of numeracy Vasilyeva et al. (2018) found that parental beliefs about the importance of school preparation were not associated with parents' informal but with formal math activities. For the domain of science, this might be different because parents may have a personal interest in science and consider science as important but still believe that science is too difficult for young children and therefore do not find it necessary to be taught in preschool. Thus, among parents with comparable structural family characteristics, personal interest additionally explains variance in the support of science-related learning activities with their children.

There are further findings from the school context indicating that parents with a weaker interest in science have more negative prior experiences in their science learning and a lower level of science knowledge and therefore are less involved in their childrenś science learning and the support of their children's science homework, although they consider science learning as important for their children (Kaya & Lundeen, 2017; Lurdes Cardoso, 2002; Shymansky et al., 2000). Together with the current results, this might suggest that parents' personal beliefs and interest in science might play a role in shaping their children's academic development from early on over and above parents' structural characteristics. In a similar vein, preschool teachers who believe that teaching science to preschool children is too hard, who believe that young children are unable to understand science topics, and who feel unprepared refrain from teaching preschool science (Conezio & French, 2002; Yoon & Onchwari, 2006). Similar beliefs might also be responsible for parents not to offer science-related learning opportunities to their children (Saçkes, 2014). There is some evidence, that although parents want their children to gain various experiences with science-related topics, they are concerned about not answering their children's question correctly because of a lack of science knowledge or even if they know the mechanisms behind the phenomena, they find it challenging to answer questions in an age-appropriate way (Silander et al., 2018). Another possible explanation might be that parents may think of science as a complex theoretical framework and therefore may not recognize possible learning opportunities because of a lack of awareness of science in everyday life. This has been shown to be the case in preschool teachers (Gomes & Fleer, 2018).

Taken together, our results show that structural family characteristics as well as parental interest in science are associated with parents' engagement in science-related learning opportunities. Therefore, we tested the hypothesis that the frequency of parents' learning engagement plays a mediating role in these effects on children's outcomes. This hypothesis was confirmed. The results underline the complex interplay of various HLE factors in explaining associations with children's development. The fact that science-related activities served as a mediator between parental education and children's achievement indicates that, in the present sample, children from socioeconomically advantaged backgrounds benefit primarily through the higher frequency of learning experiences offered by their parents. This finding adds a novel aspect to the large body of research on the impact of HLE on literacy and numeracy development in young children. Here, we provide evidence for the effects of an early science-related HLE using a reliable test instrument for childrenś knowledge while controlling for cognitive abilities.

The cross-sectional design of the study, however, does not allow to completely disentangle the direction of effects between children's knowledge about science and HLE factors. Thus, it could be the case that children with more knowledge may ask more questions about natural phenomena and this, in turn, leads parents to engage more frequently in their childrenś science learning. At least for early general cognitive development, there is evidence for reciprocal relations between children's development and parenting behavior (Tucker-Drob & Harden, 2012) giving rise to the possibility that part of the association in the current study could reflect the effect of children on parents as well. Stronger longitudinal designs for early developmental stages are needed to address questions of directionality more precisely.

Finally, in the current study, we also examined possible moderator effects such as differences in parental learning engagement for boys and girls, as a possible mechanism for early gender differences in children's science interest and knowledge (Alexander et al., 2012). However, in contrast to previous research by Alexander et al. (2012), we found no evidence to suggest that this was the case. More generally, findings regarding science-related gender effects are mixed in the literature. There is some evidence that parents of children at the age of 1 to 8 years are more likely to give explanations to boys in informal science settings (e.g., museum science exhibition) than to girls (Crowley et al., 2001b). Tenenbaum and Leaper (2003) found that especially fathers are more inclined to argue cognitively challenging with their sons and that parents tend to believe that science is more challenging for their 11 to 13-year-old daughters than it is for their sons. Findings from the preschool context regarding gender and interest in science suggest that science-learning opportunities for girls are more likely to be provided by parents when girls request them, whereas opportunities to deal with science for boys tend to be offered regardless of their interest (Alexander et al., 2012). However, the longitudinal nature of the study by Alexander et al. (2012)) reveals that gender differences emerge over time, which render them difficult to compare to the cross-sectional findings of the current study.

Taken together, this study makes a theoretical contribution to a domain-specific conceptualization of the early HLE. It shows that science-related measures of educational processes within the family are associated with science-related child outcome measures (controlling for a critical set of structural family characteristics and children's general cognitive abilities). Second, the study emphasizes the indirect associations between children's early science knowledge and the family's structural characteristics via educational processes.

## 8. Limitations

The current analyses and findings should also be considered against some limitations concerning the interpretation of our results. First, our study analyzed cross-sectional data. Consequently, our results illustrate associations but not causal mechanisms in other words the mentioned associations could work in the opposite direction as well. This is especially important regarding the connection between parental activities and childrenś knowledge. As mentioned above, it could be the case that children with higher levels of knowledge might ask more science-related questions, and parents, therefore, interact more frequently with their children. Second, the frequency of parents' science-related activities with their children was based on questionnaire data. Therefore, our analysis might be vulnerable to socially desired responses by parents. We asked parents about the frequency of science-related activities but we are not able to draw conclusions about the duration and the quality of these activities. For example, parents might provide many activities such as reading science books, being outside in nature and talk about nature, etc., but we are not able to assess parents' explanations of science-related issues to their children or how they respond to their children's questions. Therefore, future research is needed to provide insight into the quality and duration of different science-related activities and interactions between parents and their children. Third, the science-related activities assessed in the current study represent just a small subset of possible activities. Thus, future studies should examine additional activities in more detail and could include a broader range of activities and scientific ways of thinking and working (e.g., measuring, sorting). Fourth, the science test for children was developed by the researchers. Thus, future research needs to further establish its validity and reliability in larger samples. Furthermore, the test focuses only on three phenomena from the physics/chemistry domains. Including, for example, items specific for biology may have led to different results as parents might consider biology to be easier and more suitable for preschool children.

## 9. Implications

It has been well established that disparities in science are already in place before children enter formal schooling and persist (at least) until middle school (Morgan et al., 2016). At the same time, the current study is in line with previous research demonstrating that parents' involvement in their children's science learning is associated with their beliefs and interest in science-related activities (Chen, 2001; George & Kaplan, 1998; Kaya & Lundeen, 2017). Consequently, intervention efforts that aim at reducing science-related disparities should include parents as central agents in children's early learning and consider not only the family's structural characteristics but also parental beliefs and interest in science as they reveal additional indirect effects on children's knowledge about science. Considering the interplay of different HLE factors might, therefore, be crucial when designing and improving intervention programs for families as well as for preschools to help reduce early science achievement gaps.

Furthermore, intervention programs might consider different possibilities of access for families with various prior science experiences. Given that most parents prioritize other domains of learning such as literacy or numeracy over science during early childhood (Saçkes, 2014), intervention efforts targeted at parents should highlight how early science learning is connected to other domains of learning, for example to enhancing children's verbal abilities by formulating assumptions and ideas or using specific vocabulary (Alber-Morgan, Sawyer, & Miller, 2015; Henrichs & Leseman, 2014). One first step to help parents engage more in science-related learning opportunities could include raising awareness for phenomena such as melting, sinking and floating, or magnetism in daily life. Additionally, one can support parents' engagement in science-related learning by emphasizing that children are very well capable of developing compatible ideas about natural phenomena from early on. Such efforts are warranted considering the fact that science and technology represent fields of increasing importance in the everyday lives of parents and children. Viewed from a long-term perspective, children entering school with lower levels of science-related skills and knowledge are likely to encounter difficulties in their further science learning, in understanding public debates about science-related topics, and they are less likely to receive science-related career opportunities. Intervention programs should emphasize the important role of parents in their childrenś early science learning. This has become even more important during the current COVID-19 pandemic, in which parents in many educational systems have become the primary source for children's science learning. Taken together, our findings provide insights into the complex associations of factors of an early science-related HLE and highlight the critical role of parental involvement in early science education.

## Author contribution

Katharina Junge: Conceptualization, Formal analysis, Writing-original and revised draft

Daniel Schmerse: Conceptualization, Formal analysis, Writing - Review & Editing

Eva-Maria Lankes: Funding acquisition, Project administration, Supervision, Methodology
Claus H. Carstensen: Funding acquisition, Methodology
Mirjam Steffensky: Funding acquisition, Project administration, Supervision, Methodology, Conceptualization, Writing - Review & Editing

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## Appendix 1

Sample items childrenś science test

Sample item process knowledge Peter and Ute are curious if their swimwear dries faster when they put them on a
heater or when they roll them into a towel. How can they find out best?
a) measure the time on a clock
b) explore their swimwear with a magnifier
c) to feel with their hands after half an hour
*correct answer: a)*
Sample item content knowledge (evaporation and condensation):
When does water evaporate fastest?
a) when it is warm
b) when it is cold
c) when it is bright
*correct answer: a)*
Sample item content knowledge (melting and freezing):
What happens when you put water in a glass for one hour in the freezer of a refrigerator?
a) it gets a thin layer of ice
b) it turns into ice cubes
c) it stays liquid
d) I don't know
*correct answer: a), partly correct answer: b)*

## Appendix 2

Parental beliefs about science education in preschool
What do you expect from preschool regarding children's science learning? In preschool, children should…

| | Very important | Rather important | Rather unimportant | Not important at all |
|---|---|---|---|---|
| a) be prepared for elementary school. | ◦ | ◦ | ◦ | ◦ |
| a) learn about science-specific contents, which they need in school. | ◦ | ◦ | ◦ | ◦ |
| a) should be instructed to learn. | ◦ | ◦ | ◦ | ◦ |
| a) acquire science knowledge. | ◦ | ◦ | ◦ | ◦ |

Science-related activities

How often do you or someone else from your household do the following activities with your child?

| | Never | Several times a year | Once or twice a months | At least once per week |
|---|---|---|---|---|
| Reading from non-fiction books (for example about animals, plants, experiments, technology). | ◦ | ◦ | ◦ | ◦ |
| Joint reading of picture books about nature (for example about animals, plants, experiments, technology). | ◦ | ◦ | ◦ | ◦ |
| Being outside in nature and talking about nature. | ◦ | ◦ | ◦ | ◦ |
| Answering my child's questions about observations in nature. | ◦ | ◦ | ◦ | ◦ |
| Performing experiments (e.g. with water) | ◦ | ◦ | ◦ | ◦ |

## References

Alber-Morgan, S. R., Sawyer, M. R., & Miller, H. L. (2015). Teaching science to young children with special needs. In K. C. Trundle, & M. Saçke (Eds.), *Research in early childhood science education* (pp. 299–351). Springer. Eds..
Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education, 96*(5), 763–786. https://doi.org/10.1002/sce.21018.
Alonzo, A. C., & Gotwals, A. W. (2012). *Learning progressions in science: Current challenges and future directions* (Ed.). Springer Science & Business Media.
Anders, Y., Grosse, C., Rossbach, H. G., Ebert, S., & Weinert, S. (2013). Preschool and primary school influences on the development of children's early numeracy skills between the ages of 3 and 7 years in Germany. *School Effectiveness and School Improvement, 24*(2), 195–211. https://doi.org/10.1080/09243453.2012.749794.
Anders, Y., Hardy, I., Pauen, S., & Steffensky, M. (2017). Goals of science education between the ages of three and six and their assessment. In *Scientific studies on the work of the "Haus der kleinen forscher" foundation: Volume 5. Early science education – Goals and process-related quality criteria for science teaching* (pp. 30–99). Barbara Budrich Publishers.
Anders, Y., Rossbach, H.-. G., Weinert, S., Ebert, S., Kuger, S., Lehrl, S., et al. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly, 27*(2), 231–244. https://doi.org/10.1016/j.ecresq.2011.08.003.
Anthony, C. J., & Ogg, J. (2019). Executive function, learning-related behaviors, and science growth from kindergarten to fourth grade. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000447.
Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus. *American Educational Research Journal, 49*(5), 881–908. https://doi.org/10.3102/0002831211433290.
Biedinger, N. (2011). The influence of education and home environment on the cognitive outcomes of preschool children in Germany. *Child Development Research, 2011*(2), 1–10. https://doi.org/10.1155/2011/916303.
Bingham, G. E. (2007). Maternal literacy beliefs and the quality of mother-child book-reading interactions: Associations with children's early literacy development. *Early Education & Development, 18*(1), 23–49. https://doi.org/10.1080/10409280701274428.
Blums, A., Belsky, J., Grimm, K., & Chen, Z. (2016). Building links between early socioeconomic status, cognitive ability, and math and science achievement. *Journal of Cognition and Development, 18*(1), 16–40. https://doi.org/10.1080/15248372.2016.1228652.
Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology, 53*, 371–399. https://doi.org/10.1146/annurev.psych.53.100901.135233.
Bradley, R. H., Corwyn, R. F., McAdoo, H. P., & Coll, C. G. (2001). The home environments of children in the United States part I: Variations by age, ethnicity, and poverty status. *Child Development, 72*(6), 1844–1867. https://doi.org/10.1111/1467-8624.t01-1-00382.
Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In W. Damon, & R. M. Lerne (Eds.), *Handbook of child psychology: /ed.-in-chief William Damon. vol. 1* (pp. 793–828). Wiley: Theoretical Models of Human Development. Eds..
Callanan, M. A., Shrager, J., & Moore, J. L. (1995). Parent-child collaborative explanations: Methods of identification and analysis. *Journal of the Learning Sciences, 4*(1), 105–129. https://doi.org/10.1207/s15327809jls0401_3.
Carstensen, C. H., Lankes, E. M., & Steffensky, M. (2011). A model for analyzing scientific literacy in preschool children. *Zeitschrift für Erziehungswissenschaft, 14*(4), 651–669. https://doi.org/10.1007/s11618-011-0240-1.

Cattell, R. B., Weiß, R. H., & Osterland, L. (1997). *Grundintelligenztest skala 1 (CFT 1) (5. rev.)*. Hogrefe.

Chen, H. (2001). Parents' attitudes and expectations regarding science education: Comparisons among American, Chinese-American, and Chinese families. *Adolescence, 36*(142), 305–313.

Chi, M. T. H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *The Journal of the Learning Sciences, 14*(2), 161–199.

Conezio, K., & French, L. (2002). Science in the preschool classroom: Capitalizing on children's fascination with the everyday world to foster language and literacy development. *Young Children, 57*(5), 12–18.

Crowley, K., Callanan, M. A., Jipson, J. L., Galco, J., Topping, K., & Shrager, J. (2001a). Shared scientific thinking in everyday parent-child activity. *Science Education, 85*(6), 712–732. https://doi.org/10.1002/sce.1035.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001b). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science, 12*(3), 258–261. https://doi.org/10.1111/1467-9280.00347.

Crowley, K., & Galco, J. (2001). Everyday activity and the development of scientific thinking. In K. Crowley, C. D. Schunn, & T. Okad (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings* (pp. 393–413). Lawrence Erlbaum Associates. Eds.. http://www.museumlearning.org/crowley2.pdf .

Curran, F. C., & Kellogg, A. T. (2016). Understanding science achievement gaps by race/ethnicity and gender in kindergarten and first grade. *Educational Researcher, 45*(5), 273–282. https://doi.org/10.3102/0013189X16656611.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582.

DeFlorio, L., & Beliakoff, A. (2015). Socioeconomic status and preschoolers' mathematical knowledge: The contribution of home activities and parent beliefs. *Early Education & Development, 26*(3), 319–341. https://doi.org/10.1080/10409289.2015.968239.

DeWitt, J., Osborne, J., Archer, L., Dillon, J., Willis, B., & Wong, B. (2011). Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable. *International Journal of Science Education*, 1–27. https://doi.org/10.1080/09500693.2011.608197.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. Routledge.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428.

Dunst, C. J., Simkus, A., & Hamby, D. W. (2012). *Relationship between age of onset and frequency of reading and infants' and toddlers' early language and literacy development*: 5. Center for Early Literacy Learning.

Duschl, R., Maeng, S., & Sezen, A. (2011). Learning progressions and teaching sequences: A review and analysis. *Studies in Science Education, 47*(2), 123–182. https://doi.org/10.1080/03057267.2011.604476.

Eshach, H. (2006). *Science literacy in primary schools and preschools. Classics in science education*: 1. Springer.

Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology, 14*(3), 315–336. https://doi.org/10.1007/s10956-005-7198-9.

Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science, 16*(2), 234–248. https://doi.org/10.1111/desc.12019.

Ferry, T. R., Fouad, N. A., & Smith, P. L. (2000). The Role of family context in a social cognitive model for career-related choice behavior: A math and science perspective. *Journal of Vocational Behavior, 57*(3), 348–364. https://doi.org/10.1006/jvbe.1999.1743.

Fleer, M., Gomes, J., & March, S. (2014). Science learning affordances in preschool environments. *Australasian Journal of Early Childhood, 39*(1), 38–48. https://doi.org/10.1177/183693911403900106.

French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly, 19*(1), 138–149. https://doi.org/10.1016/j.ecresq.2004.01.004.

Frey, A., Taskinen, P., Schütte, K., Prenzel, M., Artelt, C., Baumert, J., et al. (2009). *PISA-2006-Skalenhandbuch: Dokumentation der erhebungsinstrumente*. Waxmann.

Funk, C., & Goo, S.K. (.2015). A look at what the public knows and does not know about science. Pew Research Center Science & Society. https://www.pewresearch.org/science/2015/09/10/what-the-public-knows-and-does-not-know-about-science/

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS: 88. *Science Education, 82*, 93–109 https://doi.org/10.1002/(SICI)1098-237X(199801)82:1<93::AID−SCE5>3.0.CO;2-W.

Gomes, J., & Fleer, M. (2018). Is science really everywhere? Teachers' perspectives on science learning possibilities in the preschool environment. *Research in Science Education* https://doi.org/10.1007/s11165-018-9760-5.

Greenfield, D. B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Fuccillo, J. (2009). Science in the preschool classroom: A programmatic research agenda to improve science readiness. *Early Education & Development, 20*(2), 238–264. https://doi.org/10.1080/10409280802595441.

Grissmer, D., Grimm, K. J., Aiyer, S. M., Murrah, W. M., & Steele, J. S. (2010). Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental Psychology, 46*(5), 1008–1017. https://doi.org/10.1037/a0020104.

Gropen, J., Kook, J. F., Hoisington, C., & Clark-Chiarelli, N. (2017). Foundations of science literacy: Efficacy of a preschool professional development program in science on classroom instruction, Teachers' pedagogical content knowledge, and children's observations and predictions. *Early Education and Development, 1*(4), 1–25. https://doi.org/10.1080/10409289.2017.1279527.

Hahn, I., & Schöps, K. (2019). Educational disparities right from the start? Relevance of structural and procedural variables for the scientific literacy of preschool children with and without a migration background. *Frühe Bildung, 8*(1), 3–12. https://doi.org/10.1026/2191-9186/a000405.

Hammer, A. S. E., & He, M. (2015). Preschool teachers' approaches to science: A comparison of a Chinese and a Norwegian kindergarten. *European Early Childhood Education Research Journal, 24*(3), 450–464. https://doi.org/10.1080/1350293X.2014.970850.

Hancock, E. S., & Gallard, A. J. (2004). Preservice science teachers' beliefs about teaching and learning: The influence of K-12 field experiences. *Journal of Science Teacher Education, 15*(4), 281–291.

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. MD: Brookes Publishing.

Hartas, D. (2011). Families' social backgrounds matter: Socio-economic factors, home learning and young children's language, literacy and social outcomes. *British Educational Research Journal, 37*(6), 893–914. https://doi.org/10.1080/01411926.2010.506945.

Henrichs, L. F., & Leseman, P. P. M. (2014). Early science instruction and academic language development can go hand in hand. The promising effects of a low-intensity teacher-focused Intervention. *International Journal of Science Education, 36*(17), 2978–2995. https://doi.org/10.1080/09500693.2014.948944.

Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: Implications for closing achievement gaps. *Developmental Psychology, 49*(1), 4–14. https://doi.org/10.1037/a0027238.

Hong, S.-. Y., & Diamond, K. E. (2012). Two approaches to teaching young children science concepts, vocabulary, and scientific problem-solving skills. *Early Childhood Research Quarterly, 27*(2), 295–305. https://doi.org/10.1016/j.ecresq.2011.09.006.

Inagaki, K., & Hatano, G. (1996). Young children's recognition of commonalities between animals and plants. *Child Development, 67*(6), 2823–2840. https://doi.org/10.1111/j.1467-8624.1996.tb01890.x.

Iruka, I. U., Dotterer, A. M., & Pungello, E. P. (2014). Ethnic variations of pathways linking socioeconomic status, parenting, and preacademic skills in a nationally representative sample. *Early Education & Development, 25*(7), 973–994. https://doi.org/10.1080/10409289.2014.892806.

Kähler, J., Hahn, I., & Köller, O. (2020). The development of early scientific literacy gaps in kindergarten children. *International Journal of Science Education, 42*(12), 1988–2007. https://doi.org/10.1080/09500693.2020.1808908.

Kallery, M. (2015). Science in early years education: Introducing floating and sinking as a property of matter. *International Journal of Early Years Education, 23*(1), 31–53. https://doi.org/10.1080/09669760.2014.999646.

Kaya, S., & Lundeen, C. (2017). Capturing parents' individual and institutional interest toward involvement in science education. *Journal of Science Teacher Education, 21*(7), 825–841. https://doi.org/10.1007/s10972-009-9173-4.

Kent, G., & Pitsia, V. (2018). A comparison of the home learning environment of families at risk of socio-economic disadvantage to national norms in Ireland. *Irish Educational Studies, 37*(4), 505–521. https://doi.org/10.1080/03323315.2018.1471409.

Kinzie, M. B., Whittaker, J. V., McGuire, P., Lee, Y., & Kilday, C. (2015). *Research on curricular development for pre-kindergarten mathematics and science*. Teacher College Record (117).

Kluczniok, K. (2017). Early family risk factors and home learning environment as predictors of children's early numeracy skills through preschool. *SAGE Open, 7*(2), Article 215824401770219. https://doi.org/10.1177/2158244017702197.

Kluczniok, K., Lehrl, S., Kuger, S., & Rossbach, H.-. G. (2013). Quality of the home learning environment during preschool age – Domains and contextual conditions. *European Early Childhood Education Research Journal, 21*(3), 420–438. https://doi.org/10.1080/1350293X.2013.814356.

LeFevre, J.-. A., Skwarchuk, S.-. L., Smith-Chant, B. L., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behavioural Science/Revue Canadienne Des Sciences Du Comportement,, 41*(2), 55–66. https://doi.org/10.1037/a0014532.

Leibham, M. E., Alexander, J. M., & Johnson, K. E. (2013). Science interests in preschool boys and girls: Relations to later self-concept and science achievement. *Science Education, 97*(4), 574–593. https://doi.org/10.1002/sce.21066.

Leseman, P. P. M., & van den Boom, D. C. (1999). Effects of quantity and quality of home proximal processes on Dutch, Surinamese-Dutch and Turkish-Dutch pre-schoolers' cognitive development. *Infant and Child Development, 8*(1), 19–38 https://doi.org/10.1002/(SICI)1522-7219(199903)8:1<19::AID−ICD187>3.0.CO;2-7.

Lurdes Cardoso, M. de (2002). Studies of Portuguese and British primary pupils learning science through simple activities in the home. *International Journal of Science Education, 24*(1), 47–60. https://doi.org/10.1080/09500690110049079.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2013). Science literacy in school and home contexts: Kindergarteners' science achievement and motivation. *Cognition and Instruction, 31*(1), 62–119. https://doi.org/10.1080/07370008.2012.742087.

Martin, M. O., Mullis, I. V. S., Foy, P., & Hooper, M. (2016). *TIMSS 2015. International results in science.*

Masters, G. N. (1982). A rasch model for partial credit scoring. *Psychometrika, 47*(2), 149–174. https://doi.org/10.1007/BF02296272.

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43*(4), 947–959. https://doi.org/10.1037/0012-1649.43.4.947.

Melhuish, E. (2010). Why children, parents and home learning are important. In K. Sylva, E. Melhuish, P. Sammons, I. Siraj-Blatchford, & B. Taggar (Eds.), *Early childhood matters: Evidence from the effective pre-school and primary education project* (pp. 44–69). Routledge. Eds..

Melhuish, E. C., Phan, M. B., Sylva, K., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2008). Effects of the home learning environment and preschool center experience upon literacy and numeracy development in early primary school. *Journal of Social Issues, 64*(1), 95–114. https://doi.org/10.1111/j.1540-4560.2008.00550.x.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher, 45*(1), 18–35. https://doi.org/10.3102/0013189X16633182.

Murphy, D. (1992). Constructing the child: Relations between parents' beliefs and child outcomes. *Developmental Review, 12*(2), 199–232 https://doi.org/10.1016/0273-2297(92)90009-Q.

Muthén, L., & Muthén, B. (1998–2012). *Mplus user's guide* (7th ed.). CA: Muthén & Muthén.

National Academies of Sciences, Engineering, and Medicine.. (2017). *Promoting the educational success of children and youth learning English: Promising futures*. The National Academies Press. https://doi.org/10.17226/24677.

Nayfeld, I., Brenneman, K., & Gelman, R. (2011). Science in the classroom: Finding a balance between autonomous exploration and teacher-led instruction in preschool settings. *Early Education & Development, 22*(6), 970–988. https://doi.org/10.1080/10409289.2010.507496.

Niklas, F., & Schneider, W. (2013). Home literacy environment and the beginning of reading and spelling. *Contemporary Educational Psychology, 38*(1), 40–50. https://doi.org/10.1016/j.cedpsych.2012.10.001.

Niklas, F., & Schneider, W. (2014). Casting the die before the die is cast: The importance of the home numeracy environment for preschool children. *European Journal of Psychology of Education, 29*(3), 327–345. https://doi.org/10.1007/s10212-013-0201-6.

OECD (Ed.). (1999). Classifying educational programmes: Manual for ISCED-97 implementation in OECD countries.

OECD. (2016a). Excellence and equity in education. *PISA 2015 results: /Organisation for economic co-operation and development, programme for international student assessment; volume 1*. OECD Publishing.

OECD. (2016b). *PISA 2015 assessment and analytical framework: Science, reading, mathematic and financial literacy*. PISA. OECD Publishing.

Oppermann, E., Brunner, M., Eccles, J. S., & Anders, Y. (2018). Uncovering young children's motivational beliefs about learning science. *Journal of Research in Science Teaching, 55*(3), 399–421. https://doi.org/10.1002/tea.21424.

Pajares, F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307–332. https://doi.org/10.3102/00346543062003307.

Pan, B. A., Rowe, M. L., Singer, J. D., & Snow, C. E. (2005). Maternal correlates of growth in toddler vocabulary production in low-income families. *Child Development, 76*(4), 763–782. https://doi.org/10.1111/1467-8624.00498-i1.

Peterson, S. M., & French, L. (2008). Supporting young children's explanations through inquiry science in preschool. *Early Childhood Research Quarterly, 23*(3), 395–408. https://doi.org/10.1016/j.ecresq.2008.01.003.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879–891. https://doi.org/10.3758/BRM.40.3.879.

Preacher, K. J., & Kelley, K. (2011). Effect size measures for mediation models: Quantitative strategies for communicating indirect effects. *Psychological Methods, 16*, 93–115.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman, & S. K. Abel (Eds.), *Handbook of research on science education*. Routledge Eds.. https://doi.org/10.4324/9780203097267.ch27.

Ross, B. H., Gelman, S. A., & Rosengren, K. S. (2005). Children's category-based inferences affect classification. *British Journal of Developmental Psychology, 23*(1), 1–24. https://doi.org/10.1348/026151004X20108.

Saçkes, M. (2014). Parents who want their PreK children to have science learning experiences are outliers. *Early Childhood Research Quarterly, 29*(2), 132–143. https://doi.org/10.1016/j.ecresq.2013.11.005.

Saçkes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. A. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the early childhood longitudinal study. *Journal of Research in Science Teaching, 48*(2), 217–235. https://doi.org/10.1002/tea.20395.

Samarapungavan, A., Mantzicopoulos, P., & Patrick, H. (2008). Learning science through inquiry in kindergarten. *Science Education, 92*(5), 868–908.

Samarapungavan, A., Patrick, H., & Mantzicopoulos, P. (2011). What kindergarten students learn in inquiry-based science classrooms. *Cognition and Instruction, 29*(4), 416–470. https://doi.org/10.1080/07370008.2011.608027.

Sammons, P., Toth, K., Sylva, K., Melhuish, E., Siraj, I., & Taggart, B. (2015). The long-term role of the home learning environment in shaping students' academic attainment in secondary school. *Journal of Children's Services, 10*(3), 189–201. https://doi.org/10.1108/JCS-02-2015-0007.

Schmerse, D., Anders, Y., Flöter, M., Wieduwilt, N., Roßbach, H. G., & Tietze, W. (2018). Differential effects of home and preschool learning environments on early language development. *British Educational Research Journal, 44*(2), 338–357. https://doi.org/10.1111/cdev.13357.

Senechal, M., & LeFevre, J.-. A. (2002). Parental involvement in the development of children's reading skill: A five-year longitudinal study. *Child Development, 73*(2), 445–460. https://doi.org/10.1111/1467-8624.00417.

Shonkoff, J. P., & Phillips, D. (Eds.). (2000). *From neurons to neighborhoods: The science of early child development*. National Academy Press Eds. http://site.ebrary.com/lib/academiccompletetitles/home.action .

Shymansky, J. A., Yore, L. D., & Hand, B. M. (2000). Empowering families in hands-on science programs. *School Science and Mathematics, 100*(1), 48–58. https://doi.org/10.1111/j.1949-8594.2000.tb17319.x.

Silander, M., Grindal, T., Hupert, N., Garcia, E., Anderson, K., Vahey, P., et al. (2018). *What parents talk about when they talk about learning: A national survey about young children and science*. Education Development Center, Inc https://eric.ed.gov/?id=ED603163.

Skwarchuk, S.-. L. (2009). How do parents support preschoolers' numeracy learning experiences at home? *Early Childhood Education Journal, 37*(3), 189–197. https://doi.org/10.1007/s10643-009-0340-1.

Smith, C. L., Wiser, M., Anderson, C. W., & Krajcik, J. (2006). FOCUS ARTICLE: Implications of research on children's learning for standards and assessment: A proposed learning progression for matter and the atomic-molecular theory. *Measurement: Interdisciplinary Research & Perspective, 4*(1–2), 1–98. https://doi.org/10.1080/15366367.2006.9678570.

Sodian, B., Zaitchik, D., & Carey, S. (1991). Young children's differentiation of hypothetical beliefs from evidence. *Child Development, 62*(4), 753–766.

Solomon, J. (2003). Home-school learning of science: The culture of homes, and pupils' difficult border crossing. *Journal of Research in Science Teaching, 40*(2), 219–233. https://doi.org/10.1002/tea.10073.

Soto-Calvo, E., Simmons, F. R., Willis, C., & Adams, A. M. (2015). Identifying the cognitive predictors of early counting and calculation skills: Evidence from a longitudinal study. *Journal of Experimental Child Psychology, 140*, 16–37. https://doi.org/10.1016/j.jecp.2015.06.011.

Steffensky, M. (2017). *Science education in preschools. Advanced training for preschool teachers: 48* (p. 48). WiFF Expertisen.

Steffensky, M., Lankes, E. M., Carstensen, C. H., & Nölke, C. (2012). Daily life and experiments: What are the appropriate learning settings for children in kindergarten? Findings from the SNaKE project. *Zeitschrift für Erziehungswissenschaft, 15*(1), 37–54. https://doi.org/10.1007/s11618-012-0262-3.

Sylva, K., Sammons, P., Chan, L. L. S., Melhuish, E., Siraj-Blatchford, I., & Taggart, B. (2013). The effects of early experiences at home and preschool on gains in English and mathematics in primary school: A multilevel study in England. *Zeitschrift Für Erziehungswissenschaft, 16*(2), 277–301. https://doi.org/10.1007/s11618-013-0364-6.

Tenenbaum, H. R., & Leaper, C. (2003). Parent–child conversations about science: The socialization of gender inequities? *Developmental Psychology, 39*(1), 34–47.

Trundle, K. C. (2015). The inclusion of science in early childhood classrooms. In K. C. Trundle, & M. Saçke (Eds.), *Research in early childhood science education* (pp. 1–6). Springer. Eds..

Trundle, K. C., & Saçkes, M. (Eds.). (2015). *Research in early childhood science education*. Springer Eds..

Tucker-Drob, E. M., & Harden, K. P. (2012). Early childhood cognitive development and parental cognitive stimulation: Evidence for reciprocal gene-environment transactions. *Developmental Science, 15*(2), 250–259. https://doi.org/10.1111/j.1467-7687.2011.01121.x.

Vasilyeva, M., Laski, E., Veraksa, A., Weber, L., & Bukhalenkova, D. (2018). Distinct pathways from parental beliefs and practices to children's numeric skills. *Journal of Cognition and Development, 19*(4), 345–366. https://doi.org/10.1080/15248372.2018.1483371.

Weigel, D. J., Martin, S. S., & Bennett, K. K. (2006). Contributions of the home literacy environment to preschool-aged children's emerging literacy and language skills. *Early Child Development and Care, 176*(3–4), 357–378. https://doi.org/10.1080/03004430500063747.

Wilson, M. (1992). The ordered partition model: An extension of the partial credit model. *Applied Psychological Measurement, 16*(4), 309–325. https://doi.org/10.1177/014662169201600401.

Yoon, J., & Onchwari, J. A. (2006). Teaching young children science: Three key points. *Early Childhood Education Journal, 33*(6), 419–423. https://doi.org/10.1007/s10643-006-0064-4.

Zady, M. F., & Portes, P. R. (2001). When low-SES parents cannot assist their children in solving science problems. *Journal of Education for Students Placed at Risk (JESPAR), 6*(3), 215–229. https://doi.org/10.1207/S15327671ESPR0603_4.

Zhang, X., Hu, B. Y., Ren, L., & Zhang, L. (2019). Family socioeconomic status and Chinese children's early academic development: Examining child-level mechanisms. *Contemporary Educational Psychology, 59*, Article 101792. https://doi.org/10.1016/j.cedpsych.2019.101792.

Zippert, E. L., & Rittle-Johnson, B. (2018). The home math environment: More than numeracy. *Early Childhood Research Quarterly*. https://doi.org/10.1016/j.ecresq.2018.07.009.