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Fostering Early Competence Development Through Home and Preschool Learning Environments—a Summary of Findings from the BiKS-3-18 Study

Simone Lehrl, Hans-Günther Rossbach and Sabine Weinert

Abstract

Growing evidence reveals powerful associations between early learning environments and children's later academic success. Besides the family, which has been shown to be a significant predictor of children's development, the longer-term benefits of early institutional experiences in the preschool are also of interest, given the high participation rate across all social milieus, and the continuously expanding sector of early childhood education and care. In this paper, we therefore present findings from the study BiKS-3-18 on the short- and long-term effects of early learning environments at home and at preschool on children's development.

The results show that the quality of the home learning environment as well as the quality of the preschool have long term benefits for children's

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socio-emotional, language, and mathematical development, although not uniformly for different developmental domains and learning environments. Thereby, the results point to the specificity of environmental impact, as different facets of the learning environments predict different domains of children's development.

Keywords

Preschool quality · Early childhood education and care · Home learning environment · Mathematical development · Language development · Socio-emotional development · Longitudinal study · Developmental growth · Lasting effects

1 Introduction

From a bioecological perspective of human development, stimulating adult-child interactions within and between ecological micro systems are crucial for children's development (Bronfenbrenner and Morris 2006). In detail, engaging children in stimulating early learning opportunities at home and in institutions is associated with comparatively higher levels of cognitive, language, mathematical, and socio-emotional competencies with positive long-lasting effects on future academic achievement (Boonk et al. 2018; Dearing et al. 2006; Park and Holloway 2017). As a consequence, parents and teachers are encouraged to support learning, and to engage in stimulating activities with children to foster children's early development and later outcomes. It is well documented that children differ already at entry to preschool in their language, (pre-)reading, and early numeracy skills and that these differences often persist later in life (e.g., Dornheim 2008; Dubowy et al. 2008; Magnuson et al. 2004; Sammons and Smees 1998; Sammons et al. 2004; Tymms et al. 1997; Weinert et al. 2010; see also Weinert and Ebert this volume). Therefore, rather than solely relying on strategies implemented in primary and secondary school, it is important to investigate relevant influencing factors that affect children's development at an earlier age. Promoting school relevant competencies is hypothesized to be a means to raise achievement levels of all children, but may be especially relevant for children from disadvantaged homes. Issues of early education have also been widely discussed in other fields like economics (Heckman 2006; Knudsen et al. 2006) and it has been argued that investing in early education programs will result in long-term monetary benefits.

Such expectations have finally led to increased state and federal support for early education programs in Germany as well. The implementation of educational plans since 2004 across all federal states that explicitly define educational domains like language or science education marks one of these developments (e.g. Smidt and Schmidt 2012). Furthermore, additional strategies have been implemented recently to put a stronger focus on the promotion of domain-specific competencies like language development (e.g., the federal program "Language Daycare Centers: Because Language is the Key to the World") in preschool settings.

However, although there was an increased attention towards the early years there is still a lack of research in this area, especially in Germany, concerning—to name some—the lasting effects of the quality of early childhood education and care (ECEC) and the early home learning environment (HLE) on child development, the interaction between different environments in predicting child development, the moderating role of child factors, the domain-specificity of environmental impact, and the question of possible compensatory effects of early education for children at risk.

Thus, the early childhood education project together with the developmental psychology project of the BiKS-3-18 study investigated the short- and long-term effects of quality in ECEC and the early HLE on children's development. We specifically focus on domain-specific and domain-general effects, the interaction between the learning environments, and the moderating role of child and family factors. The present paper gives insights in research findings from the BiKS-3-18 study regarding how learning environments at home and at preschool shape the development of children's school relevant competencies from early preschool age onwards.

Starting from a brief sketch of the main theoretical and conceptual considerations and the respective state of research, we will report results on the effects of (1) the home learning environment (HLE), (2) the quality of preschools (ECEC quality), and (3) the combined effects and possible moderators on different domains of child development, particularly language, (pre-)literacy, and math development. Finally, we integrate the findings and discuss limitations and implications for further research and practice.

2 Theoretical Frame

Our research is guided by bioecological theory (Bronfenbrenner and Morris 2006). A fundamental premise of the theory is that over the course of one's life "human development takes place through processes of progressively more com-

plex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate external environment" (Bronfenbrenner and Morris 2006, p. 797). The major interacting components of the bioecological model are processes, person, contexts, and time, with processes taking a central position as "engines of development" (p. 801). According to Bronfenbrenner and Morris (2006), proximal processes encompass interactions between individuals, as well as interactions with objects and symbols. To yield positive results, an individual needs to participate in these processes for an extended duration, allowing them to become progressively more intricate. These processes should be initiated by both the individual and the environment. Proximal processes have the capacity to diminish or offset disparities in developmental outcomes that arise from environmental variations (Bronfenbrenner and Morris 2006). Accordingly, within BiKS-3-18, learning environments at home and in preschools are seen as providers of proximal processes that shape children's development in interaction with the children's own (developing) capacities. Drawing on these theoretical assumptions, research within the BiKS-3-18 study provides a comprehensive approach to analyzing environmental effects that considers the (developing) individual characteristics of the child and the interplay between the learning environments over time.

3 The Home Learning Environment and Its Role in Shaping Children's Development

3.1 Theoretical and Conceptual Foundations

The observation of early emerging and rather stable disparities related to socioeconomic status (SES) for instance in early language and mathematical skills (see Weinert and Ebert this volume) as well as results showing a Matthew effect, i.e. an increasing gap in more sophisticated language skills in school age (e.g. Volodina et al. 2020), with a significant impact on school performance (Heppt et al. 2021; Schuth et al. 2017; Weinert and Ebert this volume), points to important influencing factors within the HLE. As assumed in bioecological models of development HLE could mediate such SES effects (e.g. Bronfenbrenner and Morris 1998). A huge body of research points to the importance of the early years HLE for children's development in various domains (see Lehrl 2018 for an overview) while concepts of HLE differ substantially. Most research applies a domain-specific approach in studying the effects of the home learning environment as suggested by Sénéchal and LeFevre (2002) for the language/literacy domain and Skwarchuk et al. (2014) for the mathematical domain. This aligns with the

concept of child development having distinct trajectories for different domains, highlighting the importance of precisely assessing how the home learning environment influences various aspects of children's development. The domain-specific approach differentiates between activities related to literacy and numeracy within the home learning environment (e.g., Manolitsis et al. 2013). Whereas home literacy activities comprise activities that deal with oral and written language (e.g., shared book reading, teaching letters; Sénéchal and LeFevre 2002), home numeracy activities entail experiences regarding numbers, shapes, and digits (LeFevre et al. 2009). Within those two—still rather broad—domains, activities can be grouped into more formal (i.e., explicit teaching) and more informal activities (i.e., integrated in play). Formal literacy activities at home include those activities that directly refer to print, like teaching letters or reading (Sénéchal and LeFevre 2002). Accordingly, formal numeracy activities include all activities that directly teach numbers and counting (Skwarchuk et al. 2014).

Informal literacy and numeracy activities refer to experiences that involve language, print, or mathematics through process characteristics, stimulating activities, or input characteristics, e.g., during joint book reading or playing board games (Sénéchal and LeFevre 2002; Skwarchuk et al. 2014).

Furthermore, based on social-constructivist theory that suggests that children actively acquire higher cognitive skills by being supported by a more experienced person in their zone of proximal development (Vygotsky 1980), interaction quality can be conceptualised as those processes that stimulate and promote children's activities beyond their current cognitive and achievement level. In the context of shared book reading, extra-textual utterances of the parent might be a means to foster a child's cognitive and language level by going beyond the actual level of development and providing the child with stimulating input and interactions; this might be especially supportive for children's development (Lehrl, Ebert et al. 2020). The complexity (Huttenlocher et al. 2010) and grade of decontextualization of the language directed to the child during shared book reading seems to be especially important (e.g., van Kleeck 2003 for an overview). The most effective strategies for improving children's language and cognitive outcomes are asking open-ended questions (Ninio 1983), discussing the story, and elaborating on the child's comments in verbal interactions (de Jong and Leseman 2001; Hindman et al. 2008, 2014; Lehrl et al. 2013). These aspects tie also in with the concept of "sustained shared thinking" (SST; Siraj et al. 2017; Siraj-Blatchford et al. 2003). SST refers to "an interaction where two or more individuals 'work together' in an intellectual way to solve a problem, clarify a concept, evaluate an activity, or extend a narrative. Both parties must contribute to the thinking, and it must develop and extend the understanding" (Siraj-Blatchford et al. 2002, p. 8). Such

kinds of dialogue are assumed to be particularly supportive to children's language and cognitive development by stimulating the child to actively engage in parent/teacher-guided situations.

Furthermore, within parallel research strands, routed in developmental psychology, even more specific indicators of verbal interactions—e.g., the parental mental state language—are discussed as important. In particular, language that is used to talk about mental states and processes (e.g., Bretherton and Beeghly 1982; Olson et al. 2006) is thought to promote the children's developing Theory of Mind (ToM) understanding, i.e., the understanding that human behavior is guided by mental states that may differ from reality (Ebert et al. 2017; Gola 2012; Ruffman et al. 2002).

In the domain of mathematics there is a small research branch conceptualizing the quality of interactions regarding mathematics as "math talk" (e.g., Klibanoff et al. 2006 for the classroom context; Levine et al. 2010; Ramani et al. 2015; Skwarchuk 2009). The findings indicated that the complexity and level of parents' and teachers' verbal expressions related to mathematics differ, such as when they mention numbers and digits, perform counting, discuss ordinal relationships, engage in calculations, identify numbers, and make comparisons between quantities and magnitudes. These variations, in turn, have a predictive impact on children's mathematical achievements (Klibanoff et al. 2006; Ramani et al. 2015; Skwarchuk 2009).

Within the BiKS-3-18 study, we were able to implement, amongst others, measures of formal and informal literacy, formal numeracy, the quality of overall verbal interaction and math talk (Lehrl, Ebert et al. 2020; see Rossbach et al. (this volume) for more information on the measures). Furthermore the amount and complexity of language input (Anderka 2018), and the parental mental state language (Ebert et al. 2017) was measured through high- and low-inferential ratings of observed parent-child-interactions including in-depth coding of video-taped and transcribed interaction situations (see Weinert and Ebert this volume) as well as via questionnaires. The scales used across the different studies thus differ in grades of specificity and will be further described at the corresponding passage of the paper.

3.2 Domain-Specific and Cross-Domain Effects of the Home Learning Environment

3.2.1 Home Literacy Stimulation and Language Development

Previous research shows in general, that the early home literacy environment is associated with children's language and literacy development (Sénéchal 2015).

Specifically, formal literacy experiences, such as teaching the alphabet, are associated with skills that precede or belong to decoding-oriented skills, like letter knowledge (Evans et al. 2000; Lehrl et al. 2012, 2013; Manolitsis et al. 2009; Torppa et al. 2006), later word decoding skills (Hood et al. 2008; Sénéchal and LeFevre 2002), and reading fluency (Sénéchal 2006). In contrast, informal literacy experiences are associated with skills that precede or belong to comprehension-oriented skills like children's vocabulary (Sénéchal and LeFevre 2002; Lehrl et al. 2012, 2013; Mol and Bus 2011; Sénéchal and LeFevre 2002; Torppa et al. 2006) and reading comprehension (Lehrl et al. 2013; Sénéchal 2006; Sénéchal and LeFevre 2002).

Regarding quality measures of verbal interaction behavior through observations, a huge body of research provides reasonable evidence that the quality of parent-child interactions during shared book reading (e.g., asking open-ended questions, using stimulating language) is associated with children's language development (Hindman et al. 2014; Huttenlocher et al. 2010; van Kleeck 2003 for similar results).

In accordance with the research findings of previous studies, the BiKS-3-18 study shows that the language and literacy stimulation at home (including activities, interactions and material supposed to stimulate language and literacy measured via questionnaires and observation) is clearly associated with children's *language skills* at the age of 3 years. In the case of vocabulary (Ebert et al. 2013) but not grammar acquisition (Weinert and Ebert 2013), it also accounts for the observed SES-related disparities; i.e. SES-related disparities in children's vocabulary largely disappear when the literacy stimulation in the children's home is included in the model (Ebert et al. 2013; Weinert et al. 2012). However, the differences in language and literacy stimulation at home do not show a general effect on the further *growth* of either vocabulary or grammar between the age of 3 to 5 years. Moreover, no interaction between language and literacy stimulation in preschools and in the families were observed (Ebert et al. 2013; Weinert and Ebert 2013; Weinert et al. 2012). Although simultaneous and time-delayed predictive relationships between language and literacy stimulation and children's language skills are documented in the BiKS-3-18 as well as in other studies, this does not necessarily imply an effect of language and literacy stimulation on children's language *progress*. In this respect, BiKS-3-18 analyses hint to subgroup-specific differences; for example, with regard to vocabulary, an effect of home language and literacy stimulation on the further increase in vocabulary is found in children who were linguistically less advanced at the age of three, but not in linguistically more advanced children (Weinert et al. 2012). Although some studies reveal HLE effects on language growth (e.g. Sénéchal and LeFevre 2014), further

literature is not consistent in addressing the question of the relation between the HLE on growth in language development. Many of the longitudinal studies focus on reading development (e.g. Niklas and Schneider 2017), use combined measures (e.g., academic skills, Tamis-LeMonda et al. 2019), or also find no effects of HLE on vocabulary growth (Schmerse et al. 2018).

Overall, it can be assumed that a general home literacy environment measure is too unspecific to show strong language promoting effects. Noteworthy, the various language promoting characteristics assessed within the BiKS-3-18 study are only moderately or not at all associated with each other. This shows that parents who are stimulating in one language facet do not necessarily have to be stimulating in other areas as well (Ebert et al. 2020; Lehrl et al. 2012; see also Attig and Weinert 2020 for similar results with even younger children). The analyses of Lehrl et al. (2012) underline the assumption that different aspects of children's language are fostered by different specific characteristics of the home learning environment which are in turn associated with different aspects of reading literacy in primary school (Lehrl et al. 2013). While the acquisition of letter knowledge proved to be associated with self-reported formal instructions by parents (frequency of learning to read or to teach the alphabet), vocabulary and factual knowledge were associated with the observed quality of stimulating parent-child interactions (e.g. interactive dialogue). With respect to the acquisition of grammar, it is especially the experience with books (e.g. frequency of shared book reading and number of books in household; Lehrl et al. 2012) and the availability of complex sentence structures in observed parent-child interactions that prove to be significant predictors (Anderka 2018). Importantly, the respective facets of language stimulation also accounted for SES-related disparities in the respective language skills thus differing for vocabulary and grammar (Anderka 2018).

With regard to even more specific indicators of the HLE, e.g., the parental mental state language (PMSL; assessed through coding of four vignettes[1]), the BiKS-3-18 study demonstrates that parents' use of mental state language is a crucial element in children's home language and literacy environment. PMSL is

[1] Every scene portrays a moment from daily life (e.g., baking a cake together; looking for lost keys) between a mother and a 4-year-old child, with four potential responses that a parent could make in the situation: two of the options are mental. Within the option including elaborated mental state language, the mother explicitly names a mental state (e.g., surprise and explains or clarifies this mental state while providing more information, e.g., "Dad doesn't know what is inside the box, because he can't see inside the box now that it is all wrapped up. If you tell him, he won't be surprised when he opens it" (Ebert et al. 2020).

notably linked to children's Theory of Mind (ToM) development, even when considering children's language proficiency and other broader aspects of the home language and literacy environment. This relationship is particularly significant for children from lower SES backgrounds (Ebert et al. 2020).

3.2.2 Home Numeracy Stimulation and Mathematical Skills

Activities concerning numbers, shapes, and digits at home have been shown to be associated with children's numerical development (see Lehrl 2018 for an overview). Similar to the home literacy research, formal numeracy activities are associated with basic numerical skills, like counting or digit naming (LeFevre, Fast et al. 2010; LeFevre, Polyzoi et al. 2010; Skwarchuk et al. 2014), and informal numeracy activities are associated with non-symbolic mathematical skills (Skwarchuk et al. 2014). However, the evidence concerning effects on symbolic-mathematical skills is mixed (Niklas and Schneider 2013, for positive, Huntsinger et al. 2016, for negative effects). Moreover, the amount and quality of "math talk" has been shown to be associated with mathematical development (Levine et al. 2010; Ramani et al. 2015). Ramani et al. (2015) for instance found, that advanced math talk (i.e., math talk involving cardinality, ordinal relations, and arithmetic) predicted pre-schoolers' advanced numerical knowledge (e.g., enumeration, cardinality, number line).

Many concepts of measuring mathematical stimulation via questionnaires in the home learning environment emerged after the launch of the BiKS-3-18-study in 2005 (e.g., LeFevre et al. 2009; Skwarchuk et al. 2014). However, as described in Rossbach et al. (this volume), we captured some aspects of mathematical stimulation especially through a semi-standardized interactional book-reading situation. Anders et al. (2012) showed that a global home numeracy indicator, comprising both, frequency of formal numeracy activities, available numerical material and quality of math talk, was not associated with children's growth in mathematical competencies. By disentangling the indicator, Lehrl, Ebert et al. (2020) documented, that the quality of math talk (verbal interaction regarding mathematical content) at the age of three was related to better mathematical competencies at preschool age and beyond (twelve years of age), even after controlling for family background characteristics such as the mother's educational level and the family's SES. The preschool math competencies mediated the predictive effect up to age 12. Formal numeracy activities in contrast showed no effects. These results point to the importance of measuring home numeracy stimulation as differentiated as the home literacy environment.

3.2.3 Cross-Domain Effects of the HLE

Although the above presented results suggest that HLE-effects are domain-specific, there are also some hints to cross-domain effects. However, there are only few studies that investigated both domains of HLE—literacy and numeracy—simultaneously and compared the effects on both developmental domains. In one of these studies, Manolitsis et al. (2013) found that formal literacy activities predicted mathematical skills as good as formal numeracy activities, and other studies showed that home literacy activities might be even better predictors for math skills (Baker 2014; LeFevre, Polyzoi et al. 2010). This could be attributed to the fact that, firstly, there are substantial correlations between domain-specific HLE scales (Lukie et al. 2014; Manolitsis et al. 2013; Skwarchuk et al. 2014) and, secondly, developmental advancements in language, literacy, and numeracy are interconnected, too (LeFevre, Fast et al. 2010; Purpura et al. 2011; Purpura and Reid 2016). One potential mechanism could be that by engaging their children in literacy-related activities at home, parents equip them with the language abilities necessary for the cultivation of mathematical skills (Anders et al. 2012). An alternative mechanism could be that parents who regularly engage in literacy activities with their children introduce mathematical terminology and concepts during those interactions (e.g., counting or discussing spatial relations while engaging in shared reading). Both aspects, namely, the encouragement of literacy and language skills, and the promotion of numeracy, could be indicative of the overall level of parental engagement in educational activities with their children. Consequently, these factors may influence children's development in both literacy and numeracy domains.

Nonetheless, Napoli and Purpura (2018) demonstrated that engagement in home numeracy activities may serve as a more potent predictor of language development compared to home literacy activities. The authors posit that this connection "may be due to the opportunity that parent–child numeracy practices present for in-depth verbal interactions. When parents scaffold their children's numeracy development, they are likely providing explanations to their children that may contribute to their vocabulary development" (p. 596). This aligns with Lehrl's (2018) suggestion that advanced 'math talk' could represent a distinct form of abstract language, a concept that has been established as a predictor of children's language development in numerous research studies (see van Kleeck 2003 for an overview). Investigating such cross-domain effects helps to understand how environmental stimulation enhances children's cognitive development across different domains.

Data of the BiKS-3-18 study allowed to include both domains of stimulation of the HLE in our predictive models on children's competence development. Similar

to the afore mentioned studies, Anders et al. (2012) found that a measure of literacy stimulation which comprised formal and informal activities in the home literacy environment predicted numerical skills even better than a measure of math stimulation, which included formal numeracy activities and quality of math talk. Similarly, with respect to the more specific HLE indicators, Lehrl, Ebert et al. (2020) found, that informal literacy stimulation (book exposure) was associated with math competencies, over and above the effect of quality of math talk. At the same time, quality of math talk was associated with language development as well, which strive in with the results of Napoli and Purpura (2018) and hints to the hypotheses provided by the authors.

Moreover, the BiKS-3-18 study documented, that effects of the home literacy environment are not only specific to language and academic domains. The home literacy environment was shown to be directly associated with the development of more cooperative and less aggressive behavior, and indirectly, via early language skills additionally with emotional self-regulation (Rose et al. 2018; see for similar results Foster et al. 2005) and also with enjoyment of learning and persistence (Richter et al. 2018). Shared reading between a caregiver and child might foster social-emotional health through aspects such as social-emotional reciprocity and emotional coregulation (Murray 2014). Parents might use shared reading situations to discuss emotions, rules, and norms based on the stories in books (Landry and Smith 2007; Rose et al. 2018).

4 Effects of Preschool Quality on Children's Development

A large number of studies indicate that high-quality ECEC is beneficial for children's development (Barnett 1998, 2011; Mashburn et al. 2008; Shonkoff et al. 2000). A widely used approach to conceptualize preschool quality is the framework of the Early Childhood Environment Rating System (Revised Edition: ECERS-R; Harms et al. 1998; see in more detail Rossbach et al. this volume). It includes teacher-child interactions, the availability and diversity of materials, and the safety as well as the overall arrangement of the preschool environment. In accordance with this framework the ECERS-R was extended by ECERS-E to measure preschool quality in specific developmental domains such as literacy and mathematics (ECERS-Extended Version, ECERS-E, Sylva et al. 2003). This framework is supported by research that demonstrated that domain-specific stimulation, beyond more general stimulation, is related to specific domains of development, including early math (e.g., Clements and Sarama 2007) and early

literacy (e.g., Lonigan et al. 2011). ECERS-R and ECERS-E were implemented within the BiKS-3-18 study. Both scales were administrated by trained observers during one typical morning in preschools (four hours) at each measurement point without implementing structured situations.

4.1 Effects of Language Stimulation in Preschool

With regard to language promotion in preschools, BiKS-3-18 data and analyses confirm and expand national and international findings, which have repeatedly shown that the effects of language promotion in institutional contexts often lag far behind those that would have been expected (Dickinson et al. 2011; Piasta et al. 2012; Roos et al. 2010). In particular, in the BiKS-3-18 study, differences in literacy stimulation in preschools did not show a significant effect on either vocabulary growth (Ebert et al. 2013; Weinert et al. 2012) or grammar acquisition (Weinert and Ebert 2013) over the preschool period. This is surprising at first glance. An explanation (see Weinert and Ebert 2017) may be that (a) the domain-specific qualities of the learning environment in the nearly 100 preschools were not very high on average and thus possibly too low. (b) In addition, the variance between preschools in their literacy stimulation was not very pronounced and thus possibly too limited to produce effects. This would have, however to be true for mathematics as well, but in this domain we find effects. Thus, (c) another explanation may be that the chosen measure of literacy stimulation may have been too unspecific and that the requirements on effective language support may be more demanding than covered by a relatively unspecific global literacy measure. Against this background, more specific measures of language stimulation should be investigated with regard to their effects on the acquisition of vocabulary and grammar (see also Huttenlocher et al. 2002) as well as with respect to their impact on other developmental domains (e.g., Ebert et al. 2020). This idea is supported by the findings of Lehrl and Smidt (2020) using BiKS data. They found positive relations between ECERS-E literacy stimulation and children's letter knowledge at age 5.

4.2 Effects of Mathematical Stimulation in Preschool

In contrast to the absent effects of preschool quality on language development, for the mathematical domain we find clear evidence for short (Anders et al. 2012, 2013) and long-term (Lehrl et al. 2016) effects of the observed math related qual-

ity in preschools, which are still evident when controlling for the quality in the primary school, which had an additional effect on class three math fluency (Lehrl et al. 2016). These findings gain importance when considering that research on associations of domain-specific preschool quality in stimulating mathematics with children's mathematical competencies is rare, especially with a focus on concurrent and longitudinal effects. For instance, Sammons et al. (2008) found a total score of academic-oriented preschool quality across the domains language, literacy, mathematics, and science (measured by the ECERS-E total score) to be associated only with mathematical competencies at age 10—cross sectionally—but not with the progress between the ages of 6 and 10 years. Within the BiKS-3-18-study, Anders et al. (2012) and Anders et al. (2013) could show that using a domain-specific approach in measuring preschool quality—quality of stimulation in mathematics (measured by the ECERS-E subscale "mathematics") resulted in increased effect sizes compared to using a more global measure of preschool quality (ECERS-R) in predicting growth of mathematical competencies between age 4 and 6 (measured by the subscale "arithmetics" of the Kaufman Assessment Battery for Children (K-ABC); Melchers and Preuß 1991). Moreover, Anders et al. (2013) also revealed positive relations of this domain-specific preschool quality scale and progress in mathematical competencies from preschool (age 5) through Grade 1 (age 7). When focusing on the further development beyond preschool, Lehrl et al. (2016) found that the domain-specific preschool quality even predicts growth in math fluency (measured by Heidelberger Rechentest (HRT [Heidelberger Calculation Test]; Haffner et al. 2005; subscales adding and subtracting) beyond the preschool years. Preschool quality was significantly associated with gains in math fluency from Grade 1 to Grade 3 even when controlling for initial mathematical competencies at age 3, social background variables, and other early (HLE) and concurrent (primary school quality) learning environments. These findings underscore the importance of examining preschool quality within specific domains, as opposed to confining research solely to general quality indicators, when evaluating its impact on mathematical outcomes.

5 Combined Effects of the Learning Environments

In addition to the independent effects of HLE and preschool quality on several developmental domains, moderated effects through the other early and middle childhood learning environments (family and primary school) as well as individual child characteristics seem to be relevant. When examining the interplay of multiple learning environments on developmental outcomes, four types of rela-

tions are possible (Miller et al. 2014): (a) additive effects, i.e., independent effects of the learning environments, (b) compensatory effects, i.e., children with worse quality in one learning environment profit more from high quality in another learning environment, (c) accumulated advantage effects, i.e., children with high quality in one learning environment profit comparatively more from high quality in another learning environment (also known as "Matthew effect", Walberg and Tsai 1983), and (d) accumulated disadvantage effects, i.e., children with low quality in all learning environments show particularly low scores on outcome measures when compared to children with different quality experiences (Watamura et al. 2011).

As reported in the sections above, the early and middle childhood home learning environment has been shown to be of great importance in explaining differences in children's academic outcomes (Anders et al. 2013; Melhuish et al. 2008; Niklas and Schneider 2014; Sammons et al. 2008; Son and Morrison 2010; Zadeh et al. 2010). When examining studies that investigated family background moderators of the effect of preschool quality on children's academic outcomes, Burchinal, Vernon-Feagans et al. (2014) resume, "while some evidence suggests higher child care quality might be more important for low-income/at-risk children than for other children, there is more evidence suggesting that child care quality is a modest predictor of academic and social skills regardless of social class" (p. 42). The limited number of studies that have explored the moderating role of HLE process variables have yielded inconsistent findings. For instance, Sammons et al. (2008) drew on data from the EPPE study and reported that the quality of preschool is crucial for children's mathematical learning progress, particularly when they receive minimal cognitive stimulation at home. Conversely, Tietze et al. (2005) did not discover any interaction effects between early HLE and preschool quality on school achievement at age 8. Similarly, the NICHD-Study found no significant interaction effects between early HLE and preschool quality on children's mathematical outcomes at age 4.5 (NICHD ECCRN 2004). Moreover, Burchinal, Lowe Vandell et al. (2014), using data from the NICHD-dataset, found that the connections between childcare quality and academic-cognitive skills at age 15 are influenced by the HLE, particularly maternal sensitivity during adolescence (age 15), but not by the HLE during early or middle childhood. As a result, while some studies support the idea of the accumulated advantage hypothesis, others lend support to the compensatory and additive hypotheses. When assessing the predictive role of the early HLE, it's crucial to consider subsequent HLE to eliminate the possibility that it's the concurrent learning environment, rather than

the early one, that predicts child outcomes, as noted in studies by Anders et al. (2013), Downer and Pianta (2006), and Toth et al. (2020).

With regard to the BiKS-3-18 study, Anders et al. (2012) found higher gains in mathematical skills during preschool with increasing preschool quality especially for children with medium or high-quality early home learning environments. This outcome indicates that the impacts of the two learning environments, do not merely add up together. Children with a moderately or highly favorable HLE appear to benefit from a high-quality preschool, while those with a less favorable HLE do not appear to gain from two years of high-quality preschool enrichment. This pattern of findings aligns with the notion that educational experiences at preschool must receive sufficient support at home to yield their full effects. Similarly, Lehrl et al. (2016), who investigated the growth of arithmetic competencies between Grade 1 and 3, observed a moderating effect of middle childhood HLE on preschool quality. Specifically, higher preschool quality was linked to greater initial math skills in Grade 1, but only when middle childhood HLE was of high quality. In simpler terms, preschool quality significantly impacts math skills related to addition and subtraction in Grade 1, but this effect is realized only when it's coupled with a high-quality middle childhood HLE. It seems, that the children from high quality early HLE's profit most from high preschool quality (Anders et al. 2012; Pinto et al. 2013) and that this association is carried forward to the initial state at Grade 1. This pattern of findings also suggests that the initial advantages experienced by children from high HLE households who attended high-quality preschools persist when they enter school, as there is no indication of catching up effects. These findings seem to be particularly relevant with regard to cooperation practices between family and preschool. Findings from other studies suggest that specific cooperation measures are related to the children's competence growth via the enrichment of the HLE (Lehrl, Floeter et al. 2020).

An important concern with regard to interaction effects is, that preschool quality effects might fade away in the long run when those children attending high quality preschools go on to attend primary schools with low instructional quality (Barnett 1998). In the absence of high instructional quality at primary school, the superior academic skills of preschooler's who attended high-quality preschools might not progress and their initial advantages may be lost (Crosnoe et al. 2010; Watamura et al. 2011; Woodhead 1988; Zigler and Styfco 1994). Based on this hypothesis, the impact of preschool quality on children's outcomes may only endure until the end of primary education, particularly if those who experienced high-quality preschool education also continue to receive a high level of instructional quality in primary school.

Within the BiKS study, Anders et al. (2013) also analyzed interaction effects of preschool quality and instructional quality in primary school on mathematical skills at age 7 and found no interaction effect. Similarly, Lehrl et al. (2016) found no interaction effects between preschool and primary school quality, suggesting additive effects of the two learning environments, as further results showed positive effects of primary school quality on arithmetic (Lehrl et al. 2016) and vocabulary development in primary school (Grosse et al. 2017).

Data from the BiKS study allows for more in-depth analysis than those reported. For example, Schmerse (2021) found that Dual-Language Learners (DLLs) showed improved language skills at a faster rate when their peers had higher abilities in the majority language, compared to DLLs in classrooms where peers had lower skills. In another paper he reported positive effects of a specific ECERS-R interaction scale on children's task persistence and a moderated mediation, where the quality effects on children's persistence, and indirectly on 2nd graders achievement were stronger for low SES children (Schmerse 2020). Moreover, Oppermann et al. (2023) showed a moderation of child's gender concerning the association between preschool quality and children's socio-emotional outcomes at 2nd grade.

6 Conclusion

This chapter presented results of the short and long-term effects of the home learning environment and preschool quality on different aspects of child development, mainly in the domains of language and mathematics. In the last about 20 years high expectations on the gains of investments in fostering early learning in the home and in preschools have been established. In general, national and international research support such expectations. However, the results are not always consistent and research deficits exist with regard to domain-specific early stimulation at home and in preschools—this is especially true for Germany. The data of the BiKS-3-18-study build a rich source for following differentiated research questions and represents one of the very few German longitudinal studies in this area.

The BiKS-3-18 study has differentiated between formal (i.e. explicit teaching) and informal (i.e. integrated in play) stimulation especially in the domains of language and mathematics. Results show, for example, that literacy stimulation at home is associated with language skills at the age of 3 years but not with language progress (vocabulary and grammar) over the preschool years. However, we find subgroup-specific differences related to developmental status. While lan-

guage stimulation at home impacts on vocabulary growth in children who were linguistically less advanced at age three this was not the case in more linguistically advanced children. This might indicate that language promoting factors in the learning environment differ across development. Further research should expand such attention to subgroup-specific effects for children with different early developmental starting points. In addition, not only general home literacy measures should further be considered since we find that parents who show stimulating behavior with respect to one language facet need not do so likewise with respect to others and that different facets of child language are fostered by different characteristics of the home learning environment. Overall and in accordance with the Specificity Principle of child development (Bornstein 2017), we found specific characteristics of the learning environment to stimulate specific facets of children's language development (vocabulary, grammar, literacy) at specific timepoints in development.

For stimulation of mathematics at home, we find that the quality of math talk at the age of three predicts better mathematical competencies at preschool age and beyond (twelve years of age). Yet, formal numeracy activities showed no effects. Therefore, research is advised to consider differentiated aspects both on the side of home stimulation and on the side of developmental domains. Further results show cross-domain effects of stimulation in certain domains at home. For example, we find that informal literacy stimulation (book exposure) is associated with math competencies over and above the quality of math talk and that the home literacy stimulation is directly (as well as indirectly via child language) associated with the development of more cooperative and less aggressive behavior and indirectly via child language with the development of children's emotional self-regulation. An important message for further research is therefore to put more emphasis on such cross-domain effects (see also Weinert and Ebert this volume).

For language stimulation at preschool, we did not find an effect on language growth or grammar acquisition. We discussed above several possible explanations. One should be mentioned here again: The quality of language stimulation in preschool was not very high; thus, at best medium level of quality may hinder visible effects on children's language development. Yet, although the quality of stimulation of mathematics was even lower, clear evidence occurred that the quality of math stimulation is related to growth of math competencies during preschool and beyond at least till Grade 3 in primary school. Similar effects could not be found for the global quality of stimulation in preschool. Since research on the effects of stimulation in mathematics in preschool is still rare, we need more studies on these relations. In addition, we need studies with a higher quality (and

variance) of stimulation in preschools in both domains language and mathematics using more refined measurement instruments for serval domains of stimulation.

The relations between quality of the learning environment at home and at preschool is—at least conceptually—controversial with the hope that a high quality of stimulation in preschool may compensate for low quality at home. Overall, research results are inconsistent, and, in the BiKS-3-18 study, we did not find compensatory effect. Rather, our results show higher gains in mathematical skills during preschool being associated with comparatively higher preschool quality for children with medium or high quality of the early home learning environment, i.e., a Matthew effect and not a compensatory effect (see similar results for reading development on the individual child level, Kuger and Lehrl 2013). We draw at least two conclusions. First, this result was found at a rather low preschool quality level and may be different for a high-quality level. Second, not only stimulation at preschools should be considered but also family programs which help to increase the home learning environment especially for children from disadvantaged families, including strengthening parent-preschool partnerships. One last important result should be emphasized. The BiKS-3-18 study finds no interaction effect between preschool and primary school quality on mathematical skills. That is, the effects of these environments are independent from each other. Thus, independently of the afore attended preschool, instructional quality at primary school is important for further mathematical development. These findings underline the importance of high interaction and instructional quality across all learning environments.

Finally, yet importantly, a replication of the BiKS-3-18 study is desirable. Since preschool participation for children under 3 years of age has enormously enlarged since the BiKS-3-18 study started, such a replication should start with even younger children. Although the Newborn Cohort Study of the German National Educational Panel Study (Attig et al. 2019) gives valuable insights into the very early developments (see, e.g., Attig and Weinert 2020; Weinert et al. 2016) it cannot replace such a study because the design of the National Educational Panel Study does not allow such intensive investigations of the interactions between qualities of the early home and preschool environments.

Further analyses of the BiKS-3-18 data will show whether there are even longer lasting effects of early childhood education at home, and in preschools on cognitive and so-called non-cognitive skills and how they might be mediated or moderated by children's development.

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