Early Childhood Research Quarterly 27 (2012) 231–244

Early Childhood Research Quarterly

Home and preschool learning environments and their relations to the development of early numeracy skills

Yvonne Anders*, Hans-Günther Rossbach, Sabine Weinert, Susanne Ebert, Susanne Kuger, Simone Lehrl, Jutta von Maurice

University of Bamberg, Germany

ARTICLE INFO

Article history:
Received 13 August 2010
Received in revised form 1 August 2011
Accepted 10 August 2011

Keywords:
Preschool quality
Home learning environment
Numeracy skills
Longitudinal study
International childcare perspectives
Cognitive development

ABSTRACT

This study examined the influence of the quality of home and preschool learning environments on the development of early numeracy skills in Germany, drawing on a sample of 532 children in 97 preschools. Latent growth curve models were used to investigate early numeracy skills and their development from the first (average age: 3 years) to the third year (average age: 5 years) of preschool. Several child and family background factors (e.g., gender, maternal education, socioeconomic status), measures of the home learning environment (e.g., literacy- and numeracy-related activities), and measures of preschool structural and process quality (e.g., ECERS-E, ECERS-R) were tested as predictors of numeracy skills and their development. The analyses identified child and family background factors that predicted numeracy skills in the first year of preschool and their development over the three points of measurement—particularly gender, parental native language status (German/other), socioeconomic status, and mother's educational level. The quality of the home learning environment was strongly associated with numeracy skills in the first year of preschool, and this advantage was maintained at later ages. In contrast, the process quality of the preschool was not related to numeracy skills at the first measurement, but was significantly related to development over the period observed. The results underline the differential impact of the two learning environments on the development of numeracy skills. Interaction effects are explored and discussed.

1. Introduction

It is well documented that children entering elementary school differ in their language, pre-reading, and early numeracy skills and that these differences are often maintained at later ages (e.g., Dornheim, 2008; Dubowy, Ebert, von Maurice, & Weinert, 2008; Magnuson, Meyers, Ruhm, & Waldfogel, 2004; National Institute for Child Health and Human Development Early Child Care Research Network [NICHD ECCRN], 2002a, 2005; Sammons et al., 2004; Tymms, Merell, & Henderson, 1997; Weinert, Ebert, & Dubowy, 2010). Promoting school readiness and better adjustment to school is hypothesized to be an efficient means of raising the achievement levels of all children, but especially of those children who experience a lack of parental support. It has been argued that investing in early education programs will have large long-term monetary and nonmonetary benefits (Heckman, 2006; Knudsen, Heckman, Cameron, & Shonkoff, 2006). These expectations have led to increased state and federal support for early education programs in Germany, and strategies have recently been implemented to foster the promotion of emerging (pre)academic skills such as language skills, numeracy, and scientific thinking at preschool. To date, however, empirical evidence on the effects of preschool education in Germany is limited (Rossbach, Kluczniok, & Kuger, 2008).

Of course, children's cognitive development and educational careers are also influenced by characteristics of the family and home learning environment (e.g., European Child Care and Education [ECCE] Study Group, 1999; Melhuish et al., 2008; Sirin, 2005; Taylor, Clayton, & Rowley, 2004). Consequently, studies evaluating the potential benefits of early years education programs need to examine the influences of the home and preschool learning environments simultaneously. This article investigates how the two environments interact in shaping the development of early numeracy skills in preschool-age children in Germany. Research conducted in other European countries and in the United States has highlighted the potential benefits of early years education programs for children's cognitive development for some years now (ECCE Study Group, 1999; NICHD ECCRN, 2002a, 2005; Sammons et al., 2004). However, emerging numeracy has received less research attention than has emerging literacy, especially with respect to the nature and effects of the home learning environment.

* Corresponding author at: Early Childhood Education, Faculty of Human Sciences and Education, University of Bamberg, Post box 1549, 96045 Bamberg, Germany. Tel.: +49 951 863 1821; fax: +49 951 863 4821.
E-mail address: yvonne.anders@uni-bamberg.de (Y. Anders).

0885-2006/$ – see front matter
doi:10.1016/j.ecresq.2011.08.003

Yet emerging numeracy is seen as one of the most significant predictors of later school success in mathematics. The present study also offers the possibility to explore how findings from a German sample reflect previous results from other countries and to identify indicators of good practice that are independent of the national context.

In the following, we first outline the available research on the characteristics and impact of the early years home learning environment and of preschool experience. We then identify the research desiderata that are addressed in the present study. Finally, we describe the study framework and formulate our research questions.

1.1. Characteristics and impact of the early years home learning environment

The quality of the home learning environment is related to the availability of educational resources, such as books, and the nature of parenting activities, such as reading to the child, using complex language, playing with numbers, counting, and taking the child to the library (e.g., Hart & Risley, 1995; Melhuish et al., 2008; Snow & Van Hemel, 2008). Studies exploring the nature and variation of early years home learning environments have found high variation between families. Structural characteristics, such as family composition, housing, and income, as well as parental educational beliefs and expectations also impact the quality of the home learning environment (e.g., Bornstein & Bradley, 2008; Dowsett, Huston, Imes, & Genettian, 2008; Tietze, Rossbach, & Grenner, 2005). Specifically, results indicate that low socioeconomic status (SES) and low parental education are moderately associated with low quality of the home learning environment (Bornstein & Bradley, 2008; Foster, Lambert, & Abbott-Shim, 2005; Melhuish et al., 2008; Totsika & Sylva, 2004). Son and Morrison (2010) recently investigated the stability of the home environment as children approach school entry. On the one hand, their results indicated that the quality of the home environment at age 36 months was highly correlated with the quality of the home environment at age 54 months. On the other hand, they found that home environments are also subject to change and seem to improve as children approach school entry.

Numerous studies using different measures of the home learning environment have shown that it has a considerable influence on young children's cognitive development and educational outcomes. For example, quality of the home environment as measured by the Home Observation for Measurement of the Environment Inventory (HOME; Caldwell & Bradley, 1984) has been found to correlate with outcomes including general cognitive ability and language (Son & Morrison, 2010; Totsika & Sylva, 2004). Other indicators of the home learning environment associated with better cognitive outcomes are quality of dialogic reading (Whitehurst & Lonigan, 1998), use of complex language (Hart & Risley, 1995), responsiveness and warmth in interactions (Bradley, 2002), and library visits (Griffin & Morrison, 1997; Melhuish et al., 2008). With respect to the development of early numeracy skills, the overall quality of the home learning environment (Blevins-Knabe, Whiteside-Mansell, & Selig, 2007) as well as mathematical activities such as counting or identifying shapes (Blevins-Knabe & Musun-Miller, 1996) have been shown to influence children's mathematical development. These findings are supported by other studies showing that parents of preschoolers can successfully provide their children with specific opportunities to use and extend their early numeracy concepts and skills (Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005; LeFevre, Clarke, & Stringer, 2002; LeFevre et al., 2009).

1.2. Characteristics and impact of preschool experience

Conceptualizations of the quality of the preschool learning environment cover multiple dimensions and relate to structural characteristics (e.g., class size, staff qualification levels), teachers' beliefs and orientations with respect to learning processes, and the process quality of the interactions between teachers and children (NICHD ECCRN, 2002b; Pianta et al., 2005). Process quality involves global aspects such as child-appropriate behavior and warm climate (Harms, Clifford, & Cryer, 1998) as well as domain-specific stimulation in areas such as verbal and (pre)reading literacy, numeracy, and scientific literacy (Kuger & Kluczniok, 2008; Sylva, Siraj-Blatchford, & Taggart, 2003). Research has provided insights into variation in preschool quality. Not only are differences across individual preschools or types of preschool settings large, but the legal framework varies greatly across countries and federal states (Cryer, Tietze, Burchinal, Leal, & Palacios, 1999; Early et al., 2007; ECCE Study Group, 1999; Sylva, 2010). Additionally, it has been shown that the level of process quality is associated with structural characteristics of the preschool setting and class (Early et al., 2010; Pianta et al., 2005; Tietze et al., 1998). Drawing on a German sample of preschools, Kuger and Kluczniok (2008) showed that different aspects of process quality (climate, promotion of literacy and numeracy) were related to the average age of the children in the class and to the proportion of children with a native language other than German.

Large-scale longitudinal studies have produced accumulating evidence for beneficial effects of preschool education on students' cognitive development and outcomes (e.g., Belsky et al., 2007; ECCE Study Group, 1999; NICHD ECCRN, 2003, 2005; Peisner-Feinberg et al., 2001; Sylva, Melhuish, Sammons, Siraj-Blatchford, & Taggart, 2004). Whereas the evidence for short- and medium-term academic benefits of early education or preschool programs seems to be compelling, findings on longer-term benefits are mixed. It seems that the process quality of the preschool attended is a crucial factor in the magnitude and persistence of beneficial effects. Indeed, the effects of high-quality preschool education or intensive programs on cognitive skills have been shown to persist up to the ages of 8, 10, 11 or even 15 years (Anders et al., 2011; Belsky et al., 2007; ECCE Study Group, 1999; Gorey, 2001; Peisner-Feinberg et al., 2001; Sammons, Sylva, et al., 2008; Vandell et al., 2010).

1.3. Interactive effects of home and preschool learning environments

It is accepted that the effects of preschool education can be reliably evaluated only if family and home characteristics are considered at the same time. Whereas older studies tended to control for socioeconomic and family background characteristics without investigating the distinct influence of the home learning environment on development, recent studies have examined the influence of both factors (e.g., Melhuish, 2010; NICHD ECCRN, 2006). Nevertheless, few studies have yet explicitly analyzed the interactive effects of the two environments, although the potential benefits of the amount and quality of preschool education may depend on the quality of the home learning environment and vice versa. The findings of Burchinal, Peisner-Feinberg, Pianta, and Howes (2002) indicate that maternal education, parents' caregiving practices, and parents' attitudes are the strongest predictors of child outcomes, even among those children who experience full-time nonmaternal childcare. Adi-Japha and Klein (2009) examined the associations of parenting quality with cognitive outcomes such as receptive language and school readiness among children experiencing varying amounts of childcare. They found stronger associations among children who experienced medium amounts of childcare than among those who experienced high amounts of childcare. However, the associations were not weaker among children who experienced primarily maternal care. The findings of Brooks-Gunn, Han, and Waldfogel (2010) indicate that maternal employment during the first year of life may be associated with the amount of childcare, but may also be positively related to the quality of the childcare and home environments.

Findings on interactive effects of childcare quality and quality of the home learning environment are mixed. Summarizing its results, the NICHD study group (NICHD ECCRN, 2006) stated, "we do not see a consistent pattern suggesting more optimal outcomes associated with childcare for the lowest parenting quartile or less optimal outcomes associated with childcare for the highest parenting quartile" (p. 110). Bryant, Burchinal, Lau, and Sparling (1994) found positive effects of classroom quality on cognitive outcomes, with children from stimulating home environments seeming to benefit even more from high-quality preschool than children from less stimulating homes. In contrast, after analyzing the combined effects of preschool experience and home learning environment on cognitive outcomes at age 10, Sammons, Anders, et al. (2008) concluded that the quality of the home learning environment is especially important for children who are not in preschool or who attend low-quality or low-effective preschools. In turn, the quality and effectiveness of the preschool setting is critical for children's learning progress, especially when they receive little cognitive stimulation at home. Hence, the few studies examining interactive or compensatory effects of home and preschool learning environments on children's cognitive development have produced an inconsistent pattern of results.

1.4. Desiderata for research

This study addresses research questions and methodological issues that have received little attention in existing empirical research. Its first focus is on the domain specificity of cognitive stimulation in home and preschool settings. Specifically, numeracy involves other facets of knowledge than does verbal and (pre)reading literacy (e.g., numbers and quantities as opposed to letters and sounds). It seems reasonable to assume that numeracy-related activities and stimulation, such as counting or teaching numbers, are especially beneficial for the development of numeracy skills. However, language skills and general cognitive mechanisms relevant for the acquisition of (pre)reading literacy may also foster early numeracy skills (e.g., Aiken, 1972). For example, children need both linguistic competence and domain-general skills such as logical thinking to take advantage of instruction. Thus, verbal and (pre)reading-related activities and stimulation may also foster the development of numeracy skills. In any case, it seems necessary to disentangle the effects of the two domains.

Indeed, established concepts and measures of the process quality of preschool distinguish between learning opportunities for emerging reading literacy and numeracy (Kuger & Kluczniok, 2008; Sylva et al., 2003). When investigating the impact of process quality on children's cognitive outcomes, however, researchers often use global quality indicators rather than distinguishing the two domains. Most definitions of the early years home learning environment either focus on verbal and (pre)reading-related activities and resources (e.g., Griffin & Morrison, 1997; Leseman, Scheele, Mayo, & Messer, 2007; Neuman, Copple, & Bredekamp, 2000) or do not differentiate between activities promoting verbal literacy or numeracy (e.g., Adi-Japha & Klein, 2009; Bryant et al., 1994; Burchinal et al., 2002; Melhuish et al., 2008). Comparatively few studies have focused exclusively on numeracy-related activities in the family and their relations to numeracy skills or mathematics achievement (e.g., Blevins-Knabe & Musun-Miller, 1996; LeFevre et al., 2009; Starkey, Klein, & Wakeley, 2004; Tudge & Doucet, 2004). In this study, we distinguish between the two domains and demonstrate the value of such an approach.

An important methodological challenge relates to the age of the children at entry to preschool and to the study. By the time children enter preschool (e.g., at age 3 years), various factors—especially the home learning environment—may already have influenced their cognitive development for some time, and the differences in competencies and skills associated with the home learning environment may be maintained throughout the preschool period. Additionally, researchers are often only able to begin recruiting children at entry to preschool, meaning that children have been in preschool for several months before their cognitive skills are measured for the first time. Thus, some of the variation in the baseline assessment may be a result of preschool experience and its quality. The possible impact of children's previous experiences on the baseline measure is often disregarded in the choice of statistical methods and the discussion of findings; this may result in the underestimation and undervaluation of the effects of the home learning environment or preschool experience.

Third, the few existing findings on the interactive effects of home and preschool learning environments reveal the need for more studies examining these complex relations in depth. The present study was designed to contribute to a better understanding of how home and preschool learning environments are related to the development of early numeracy skills, addressing all of the points mentioned above.

1.5. The present study

This study is part of the longitudinal BiKS project on Educational Processes, Competence Development, and Selection Decisions at Pre- and Elementary School Age (German: Bildungsprozesse, Kompetenzentwicklung und Selektionsentscheidungen im Vor- und Grundschulalter), which was funded by the German Research Foundation (DFG). The BiKS 3–10 substudy tracks the development of 547 children attending 97 preschools in two German federal states (Bavaria and Hesse) since 2005. Preschool is voluntary in Germany, and most preschoolers start at the age of 3 years. Unlike preschool settings in many other countries, children are often placed in mixed-age classes. Thus, the age of children within one class often ranges between 3 and 6 years. BiKS 3–10 has collected a wide range of data on the children, their family background, and the preschools they attended, making it possible to investigate the children's cognitive development, the influences of family background and preschool, and the formation of educational decisions (Schmidt et al., 2009; von Maurice et al., 2007). In particular, the study aimed to provide a complete picture of children's learning environments at preschool age. Whereas most previous studies have assessed the home learning environment solely by means of parental questionnaires and interviews focusing on resources and parental activities promoting early literacy, BiKS combined interviews and questionnaires with observations in the families and distinguished between resources and activities related to verbal or (pre)reading literacy, on the one hand, and numeracy, on the other. A repeated measurement design was implemented for home and preschool characteristics as well as for the outcome measures. BiKS thus goes far beyond previous studies (ECCE Study Group, 1999) on educational careers and their influencing factors in this age range in Germany.

In the present investigation, we explore early numeracy skills and growth in this cognitive domain over two years of preschool (age 3–5 years), addressing five research questions. First, we seek to identify the influence of several child and family background factors (e.g., gender, SES, maternal education) on developmental progress. Second, we examine the influence of different aspects of the home learning environment (quality of stimulation in numeracy and [pre]reading literacy) on development. Third, we test the power of measures of preschool experience (structural and process quality characteristics in different domains) to predict the development of numeracy skills. Fourth, we investigate whether the effect of preschool quality on baseline achievement level and growth depends on the amount of time the child has spent in that preschool at study entry. Finally, it examines whether the effect of preschool process quality is the same among children exposed to home learning environments of different qualities.

2. Methods

2.1. Procedure and sample

All data were obtained in the context of the BiKS 3–10 study (von Maurice et al., 2007). The sample consisted of 532 children for whom at least one valid outcome measure and predictor were available (i.e., 97.28% of the original sample recruited from 97 preschool classes in 2005). It was drawn from eight regions in two federal states (Bavaria and Hesse) that cover a wide range of living conditions in Germany in terms of environmental conditions as well as family socioeconomic and cultural backgrounds. The target population was children due to be enrolled in school in fall 2008. Trained examiners tested the children individually. The average number of children assessed per class was 5.48. Note that this number is not equivalent to class size, as most preschool classes consisted of mixed age groups, such that not all children in a class met the inclusion criterion.

Assessments included a battery of standardized tests covering the domains of verbal development, non-verbal reasoning, memory, and specific school-relevant skills. In the present study, we analyze the development of early numeracy skills over three measurement points. The participating children were aged on average 37 months at preschool entry (min. = 23, max. = 50), 45 months at the first assessment (min. = 34, max. = 57), 56 months at the second assessment (min. = 46, max. = 67), and 68 months at the third assessment (min. = 58, max. = 76). The vast majority of children were in their first of three years of preschool education at baseline assessment, and the interval between each of the assessments was approximately one year. Accordingly, for most participating children, the three measurement points covered the first, second, and third year of preschool experience. The age range observed was mainly an effect of the differing school enrolment procedures in the federal states of Bavaria and Hesse. In addition to cognitive outcomes, data on a wide range of background variables was collected through parental interviews and questionnaires. Parents reported on their family structure, occupational and educational background, and parent–child activities and routines. Further information on the child's home environment was obtained through observations conducted each year in the participating children's homes. Structural characteristics and measures of preschool process quality were obtained through interviews with the heads of the preschools, staff questionnaires, and observations. Staff interviews were conducted twice a year, and two observations of the preschool settings were conducted between the first and third measurement.

Of the children (48.12% girls), 9.96% had one parent with a native language other than German and 9.59% had two parents with a native language other than German. With respect to maternal education, 24.44% of mothers had no qualifications or had graduated from the vocational track of the three-tier German secondary system, 35.53% had graduated from the intermediate track, and 34.02% had graduated from the academic track. The remaining 5.26% held any other type of qualification. Due to the sampling design, 65.23% of the children were from Bavaria and 34.78% from Hesse. The sample can be assumed to be representative of the regions and federal states selected.

2.2. Measures

2.2.1. Outcome measures

Children's early numeracy skills were assessed using the arithmetic subscale of the German version of the Kaufman Assessment Battery for Children (KABC; Melchers & Preuss, 2003). This scale measures children's skills in counting, identifying numbers, knowledge of shapes, and understanding of early mathematical concepts like addition or subtraction. Although the instrument does not cover all aspects of numeracy development during preschool age, it is internationally well known and established. Numeracy skills as covered by the arithmetic subscale are considered to be predictive for later mathematics achievement in school (Dornheim, 2008; Jordan, Glutting, & Ramineni, 2010). In contrast to other instruments, it can be applied over a wide age range.

The test is organized into sets of three to five items of increasing difficulty. Testing is stopped when a child answers all items in a subset incorrectly. The test items are embedded in a story about a family visiting a zoo, which is presented verbally with accompanying pictures. In sets 1 and 2, the child has to count objects, identify numerals up to 10, and identify two-dimensional shapes (e.g., point to a triangle). In sets 3 and 4, the child has to solve various numerical problems in the number range up to 10: comparing quantities of pictured objects (e.g., "Are there more children or more seals?"), understanding numbers as symbols (e.g., "What number is missing here?"), and solving verbally presented subtraction problems supported by pictures. In sets 4 and 5, the child has to read numbers greater than 10, solve verbally presented arithmetic problems (subtraction and addition) that cross the "10" boundary, and do simple multiplication and division tasks (e.g., "The zoo has twice as many giraffes as goats. The zoo has five goats. How many giraffes are there in the zoo?"). From set 6, children's skills in dealing with numbers higher than 100 and with scale units are assessed, as well as their ability to solve more complex multiplication and division tasks embedded in the story. Children score one point for each item answered correctly. In this study, we used raw scores in the further analyses, allowing change over time to be more easily documented.

2.2.2. Predictors

2.2.2.1. Child and family background factors. Various child and family background factors may influence children's achievement and progress. The present sample is relatively large. Nevertheless, the number of child and family background factors included in the analyses needed to be kept within a reasonable level to ensure the reliability of the estimates and to avoid problems of multicollinearity. Based on the literature and after careful preliminary analyses, we selected the following set of variables: gender, age in months, parental native language status (German/other), highest socioeconomic status in the family (SES), maternal education, and age at entry to preschool. The International Socioeconomic Index of Occupational Status (ISEI; Ganzeboom, De Graaf, & Treiman, 1992) was used as a measure of family SES. This measure is based on income, indicators of educational level, and occupation.

2.2.2.2. Home learning environment (HLE). Characteristics that indicate the capacity of the early years home learning environment to promote (pre)reading literacy and numeracy skills were assessed by (a) specially constructed questionnaires and interviews, (b) the adapted version of the Early Childhood Home Observation for Measurement of the Environment (HOME 3–6; Caldwell & Bradley, 1984), and (c) a semi-standardized reading task called the Family Rating Scale (Kuger et al., 2005). In this task, the primary caregiver and the child were asked to jointly read a picture book provided by the researcher. The pictures in the book (e.g., showing a zoo, a circus, a train station, a doctor's office, and a bakery) included numbers and letters, different sets of objects, shapes, and patterns.

These hidden cues could be used by the parent to develop the child's understanding of mathematical and language concepts. The quality of interactions between the primary caregiver and the child were rated by trained observers using a standardized rating system.

Two scale measures were developed to assess the quality of the home environment in terms of promoting (pre)reading literacy and numeracy skills, based on data from all three sources. The HLE verbal and (pre)reading literacy scale contains 10 items tapping literacy-related activities and access to material that stimulates verbal and (pre)reading literacy experiences. Items from the HOME inventory included the composite score were toys for free expression, number of children's books, books in the household, stimulation to learn the alphabet, and stimulation to learn to read. Items from the Family Rating Scale were use of questions in interaction, amount of free discussion, interactions regarding letters, and phonological cues. Additionally, the parent questionnaire tapped frequency of shared book reading. Internal consistency (Cronbach's alpha) at the three measurement points was 0.60, 0.67, and 0.63, respectively. The HLE numeracy scale consists of 10 items tapping numeracy-related activities and access to materials thought to stimulate numeracy experiences. Items from the HOME inventory were toys to teach colors and shapes, toys to learn numbers, stimulation to learn shapes, stimulation to learn colors, stimulation to learn spatial relationships, stimulation to learn digits, stimulation to learn counting. Items from the Family Rating Scale were interaction regarding digits, interaction regarding shape and space, and interaction regarding comparing and classifying. Internal consistency (Cronbach's alpha) at the three measurement points was 0.66, 0.73, and 0.71, respectively. For the following analyses, the scales were standardized to have a potential range from 0 to 1, and two indicators representing overall quality in promoting (pre)reading literacy and numeracy were derived by taking the means of the composites over the three measurements. The correlation between the two scales was moderate, at $r = 0.62$, indicating that cognitive promotion of the two domains at home was both interrelated and distinct.

2.2.2.3. Structural (quality) characteristics of the preschool. These factors included the proportion of children whose parents had a native language other than German, class size, child–staff ratio, amount of space (m^2) per child, average age of the class, and federal state. Staff qualification levels could not be included in the analyses due to the current lack of variance among preschool teachers in Germany.

2.2.2.4. Indicators of preschool process quality. This measure was based on researchers' observations of each preschool setting on the German versions of the ECERS-R (Harms et al., 1998; Tietze, Schuster, Grenner, & Rossbach, 2007) and the ECERS-E (Rossbach & Tietze, 2007; Sylva et al., 2003). The ECERS-R is a measure of the global quality of preschools, capturing aspects of the physical setting, curriculum, caregiver–child interactions, health, safety, scheduling of time, indoor and outdoor play, spaces, teacher qualifications, play materials, administration, and meeting staff needs. The ECERS-E focuses on four educational aspects: the quality of learning environments for verbal literacy, mathematics, and science literacy, and catering for diversity and individual learning needs. The overall ECERS-R and ECERS-E scores as well as the ECERS-E literacy and mathematics scales are used in the following analyses. Although some preschool characteristics are naturally subject to change (e.g., class composition), the correlations between the measurement points were moderate. To keep the complexity of our statistical models within reasonable limits, we used average scores across the three measurement points for all preschool measures in the following analyses. As measures of central tendency over time, these means are more accurate than a measure based on a single assessment.

2.3. Statistical analyses

We examined influences on the development of numeracy skills over three repeated measurements (numeracy skills at first, second, and third assessment) by fitting latent linear growth models to the data using MPlus version 5.2 (Muthén & Muthén, 2008). Model fit was evaluated with reference to the RMSEA and CFI, using the criteria suggested by Hu and Bentler (1999). The data have a nested structure, with children being nested in preschool classes. Although the number of children per preschool class was rather low, ignoring the multilevel structure might have led to unreliable standard errors of the coefficients in the model (Raudenbush & Bryk, 2002). Thus, standard errors adjusted for the multilevel structure of the data were estimated. Missing data are a potentially serious problem in all large-scale longitudinal studies; in our study, missings on individual variables ranged from 0 to 19%. There is growing consensus that imputation of missing observations or maximum-likelihood approaches are preferable to ad hoc methods such as pairwise or listwise deletion (Enders & Bandalos, 2001; Graham & Hofer, 2000; Little & Rubin, 1987). Therefore, we chose the full information maximum likelihood (FIML) approach (e.g., Arbuckle, 1996) implemented in MPlus, which uses all available data to estimate model parameters. Selection bias may be another serious problem in nonrandomized longitudinal studies that can potentially lead to unreliable results (e.g., NICHD ECCRN & Duncan, 2003). Preliminary analyses indicated that selection bias was low in the present sample. However, to account for possible bias, we chose a covariate approach and included child and family background indicators (e.g., SES, maternal educational level, parental native language status) that might be correlated with the outcome as well as with indicators of the quality of learning environments. A stepwise analysis procedure was used, as illustrated in Fig. 1.

First, a null model with an intercept representing initial achievement and a linear slope representing growth was specified, considering only age at assessment as a predictor of numeracy skills. We assumed the outcome measures to be highly sensitive to children's age. Because the interval between assessments was not identical for all children, age at assessment was therefore treated as a time-varying predictor (null model). Child and family background factors were then tested as factors potentially influencing initial achievement level (intercept) and growth (slope) (Model 1). In a next step, we tested the predictive power of the quality of the home learning environment, controlling for the child and family background factors used in Model 1. The two HLE indicators (literacy and numeracy) were examined separately (Models 2a and 2b), allowing us to disentangle the effects of domain-specific cognitive stimulation in the home environment. Third, the structural (quality) characteristics of preschools were included in the model, while controlling for child and family background factors and the HLE indicators (Model 3). In the fourth step, indicators of preschool process quality (ECERS-R, ECERS-E, ECERS-literacy, ECERS-numeracy) were tested individually, while controlling for child, family background, HLE, and preschool structural characteristics (Models 4a–d). The effects of the indicators of preschool process quality were tested separately, allowing us to disentangle the effects of domain-specific cognitive stimulation in preschool. Finally, interaction terms were specified and included in the model (not shown in Fig. 1). Note that we adopted a sociosystemic approach and adjusted the stepwise analysis procedure accordingly. In this approach, the effects of process indicators are examined while controlling for background and structural characteristics. Similar analysis strategies have been used in other studies (e.g., Sammons, Anders, et al., 2008; Sammons, Sylva, et al., 2008).

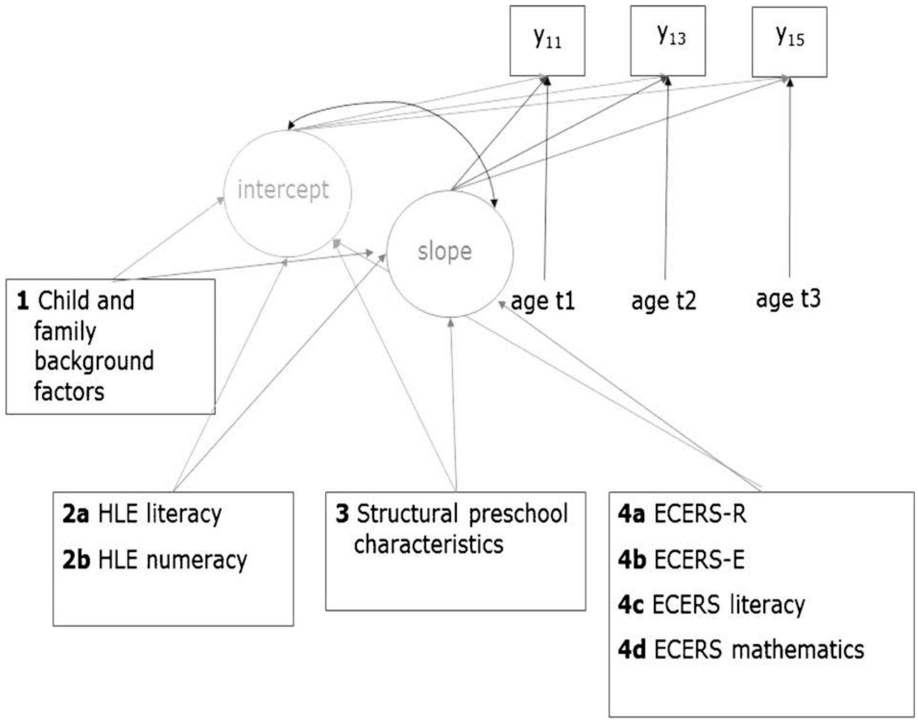

Fig. 1. Latent growth curve analysis: stepwise procedure.

However, the pattern of results obtained in our study remained stable when the order in which the predictors were included in the model was changed.

All continuous predictors were *z*-standardized before being included in the model. Preschool indicators were centered at preschool level. Afterwards, coefficients were partially standardized using the variances of the continuous latent variables only.

3. Results

First, we present the descriptive data that motivated the multivariate analyses. We then report the results of the latent growth curve models and answer the research questions addressed.

3.1. Descriptive findings

Table 1 shows descriptive statistics for the outcome measures, the aggregated scales assessing quality of the home learning environment, as well as structural characteristics and process quality indicators of the participating preschools. Descriptives reported for the home learning environment and preschool characteristics are mean scores of all available measures (questionnaires, observations) across the three measurement points.

The results show that children's mean arithmetic scores increased significantly over time. The overall mean HLE scores (possible range: 0–1) indicated significantly higher average scores for literacy ($M = 0.53$) than for numeracy ($M = 0.53$), $t = 17.83$, $df = 512$, $p < 0.001$, suggesting that literacy-related parent–child activities (e.g., reading to the child) were more frequent in our sample than were numeracy-related activities (e.g., counting with the child), and that the children had better access to books to than toys and games that facilitate the learning of numbers. With regard to preschool characteristics, the indicators of process quality are of particular interest (note that the possible range of ECERS ratings is 1–7). We considered preschools rated lower than 3 as being of low quality, those rated between 3 and 5 as being of medium quality, and those rated 5 and above as being of high quality (Harms et al., 1998; Sylva et al., 2003). On average, the quality of preschools in our sample, especially in terms of promoting domain-specific skills and abilities (ECERS-E, ECERS-mathematics, ECERS-literacy), can thus be described as low or medium. Indeed, this pattern seems to be representative for preschools in Germany (Kuger & Kluczniok, 2008; Tietze et al., 1998) and other countries (e.g., Sylva, 2010).

Bivariate correlations among all predictor variables were also examined before the multivariate analyses were conducted.

Table 1
Descriptive statistics.

Characteristic	*M*	*SD*	Min.	Max.
Child level ($N = 532$)				
Outcome				
Arithmetic score t1	4.96	3.37	0	14
Arithmetic score t2	10.40	3.91	0	20
Arithmetic score t3	15.08	3.74	2	27
Home learning environment				
HLE-literacy	0.53	0.12	0.06	0.84
HLE-numeracy	0.44	0.14	0	0.81
Preschool level ($N = 97$)				
Structural characteristics				
Class size	19.83	4.84	5	50
Average age of children in the class	5.01	0.28	3.67	5.60
Child–staff ratio	10.67	2.70	5.13	21.50
Proportion of children whose parents had a native language other than German	0.21	0.22	0	0.89
Amount of space (m^2) per child	3.55	2.82	1.46	19.62
Indicators of process quality				
ECERS-R	3.73	0.58	2.39	5.03
ECERS-E	2.88	0.58	1.63	4.07
ECERS-literacy	3.24	0.74	1.67	4.75
ECERS-mathematics	2.52	0.84	1.17	4.50

Note: Arithmetic scores are average raw scores (non-standardized). Indicators of the home learning environment and preschool characteristics are average scores across the three measurement points.

Most correlations were low to moderate. However, there was no indication of multicollinearity problems in the subsequent analyses.

3.2. How do child and family background factors and home learning environment relate to the development of numeracy skills? (Models 1, 2a, 2b)

The relations between child and family background factors, home learning environment, and the development of numeracy skills were examined using growth curve models as described above. The null model considering only age at assessment as a time-varying predictor confirmed the linear growth of numeracy skills over time and that child age was a significant predictor at all measurement points (year 1: $b = 0.47$, year 2: $b = 0.49$, year 3: $b = 0.44$, $ps < 0.001$, unstandardized coefficients). In Model 1, child and family background factors were included as further predictors (Table 2). We found that mother's education had a significant influence on initial numeracy skills (intercept) but not on later growth (slope), whereas gender, parental native language status, and SES explained variance in the intercept as well as in the slope. Girls started with a higher level of numeracy ($b = -0.36$, $p < 0.001$), but boys caught up over the period of investigation ($b = 0.60$, $p < 0.001$). Children whose parents' native language was not German had lower numeracy levels at the first assessment, especially if both parents had a native language other than German ($b = -1.21$, $p < 0.001$). However, this group of children also showed relatively stronger growth ($b = 1.01$, $p < 0.001$), catching up with their peers, although not closing the achievement gap completely. Inspection of the mean KABC raw scores illustrates this point: Children whose parents both had a native language other than German had mean arithmetic scores of 2.22 at age 3 and 13.28 at age 5. By comparison, children of native German speakers had mean scores of 5.25 at age 3 and 15.25 at age 5. Thus, the mean difference between the two groups is notably reduced, despite a slight increase in the variance. With respect to the influence of SES, children with higher SES already had higher numeracy scores at the first assessment ($b = 0.13$, $p < 0.05$), and the achievement gap widened over the following two years ($b = 0.25$, $p < 0.01$). Model 1 explained 27% of the variance in the intercept and 23% of the variance in the slope; model fit was moderate to good (CFI = 0.96, RMSEA = 0.06).

In Models 2a and 2b, the two HLE indicators were included separately as additional predictors. The results showed that the quality of the home learning environment already explained substantial variance in numeracy at the first assessment, when children were on average 3 years old. There was no significant effect of HLE on the slope, indicating that the early advantages of children with a high-quality HLE were maintained over the next two years. The coefficients (HLE-literacy: $b = 0.29$, HLE-numeracy: $b = 0.14$) also indicate that the quality of the home environment in terms of promoting literacy skills (number of books in the household, frequency of activities such as reading to the child, etc.) was more strongly correlated with initial numeracy skills than was the quality of the home environment in terms of promoting numeracy skills (availability of games facilitating learning numbers, frequency of activities such as counting, etc.). Several possible explanations for this rather counterintuitive finding are addressed in Section 4.

A further result worth noting is the decrease in the influence of family background factors when home learning environment was included in the model. Comparison of Models 2a and 2b with Model 1 reveals that the influences of maternal educational level and SES on the intercept were remarkably reduced, suggesting that part but not all of the relation between family background and numeracy is explained by the quality of the home learning environment. This

Table 2
Results of latent growth curve analyses predicting the development of numeracy skills from the first to the third point of measurement.

Predictors	Model 1				Model 2a				Model 2b			
	Intercept		Slope		Intercept		Slope		Intercept		Slope	
	B	*SE* (*B*)	*B*	*SE* (*B*)	*B*	*SE* (*B*)	*B*	*SE* (*B*)	*B*	*SE* (*B*)	*B*	*SE* (*B*)
Child and family background factors												
Age at entry to the preschool setting	−0.12#	0.06	0.14#	0.08	−0.11#	0.06	0.15#	0.08	−0.14*	0.07	0.13#	0.08
Gender (0 = female, 1 = male)	−0.36*	0.10	0.60*	0.16	−0.34*	0.09	0.60*	0.16	−0.37*	0.09	0.60*	0.16
Parental native language status (reference category: none)												
One parent	−0.62*	0.19	−0.12	0.28	−0.56*	0.20	−0.10	0.28	−0.59*	0.20	−0.11	0.28
Both parents	−1.21*	0.19	1.01*	0.23	−1.00*	0.20	1.08*	0.26	−1.10*	0.20	1.08*	0.25
Mother's education (reference category: no qualifications or vocational-track qualification)												
Intermediate-track qualification	0.24*	0.12	0.25	0.21	0.10	0.11	0.20	0.21	0.21#	0.12	0.24	0.21
Academic-track qualification	0.43*	0.15	0.03	0.25	0.17	0.14	−0.06	0.28	0.40*	0.15	0.03	0.25
Any other qualification	0.66*	0.21	−0.03	0.42	0.63*	0.22	−0.04	0.41	0.67*	0.21	−0.04	0.41
Highest SES of the family	0.13*	0.06	0.25*	0.10	0.08	0.07	0.24*	0.09	0.12#	0.06	0.24*	0.09
Home learning environment (HLE)												
HLE-literacy					0.29*	0.07	0.09	0.11				
HLE-numeracy									0.14*	0.05	0.09	0.09
Slope with intercept	*B* = 0.27		*SE* = 0.18		*B* = 0.27		*SE* = 0.19		*B* = 0.27		*SE* = 0.18	
R^2	0.27*		0.23*		0.33*		0.24*		0.29*		0.24*	
CFI/RMSEA	0.96/0.06				0.97/0.06				0.96/0.06			

Note: In all models, age at assessment was included as time-varying predictor, although not shown in the table. Coefficients were standardized using the variances of the continuous latent variables (Std – standardization).
* $p < 0.05$.
# $p < 0.10$.

effect was more pronounced for HLE-literacy, but was also evident for HLE-numeracy.

3.3. *How do preschool structural and process quality characteristics relate to the development of numeracy skills? (Models 3, 4a–d)*

To examine the influence of preschool characteristics on early numeracy skills and development, we added indicators of preschool experience to the growth models. Model 3 includes structural characteristics of the preschool as potential predictors, controlling for all child and family background factors tested in Model 1 as well as the two HLE indicators (literacy and numeracy). The inclusion of structural characteristics did not change the significance of the predictors included in Model 1. Hence, for reasons of readability, they are not shown in the following tables of results. The findings summarized in Table 3 indicate that the average age of the class ($b = 0.13$, $p < 0.01$) and the size of the preschool setting in m^2 per child ($b = 0.13$, $p < 0.01$) were positively related to initial numeracy skills. Child–staff ratio was negatively associated with initial numeracy skills ($b = -0.11$, $p < 0.05$), and the proportion of children whose parents had a native language other than German just failed to reach statistical significance ($b = -0.14$, $p = 0.053$). None of the preschool structural characteristics examined had a significant influence on the slope, suggesting that differences due to structural characteristics found at the first point of measurement remained stable over the next two years. Model 3 explained 38% of the variance in the intercept and 28% of the variance in the slope; model fit was moderate to good (CFI = 0.96, RMSEA = 0.06).

Models 4a–d tested the influence of indicators of process quality. None of the indicators considered had a significant effect on initial numeracy levels (see Tables 3 and 4). Global quality as measured by the ECERS-R just failed to reach statistical significance in its influence on growth over the preschool period ($b = 0.14$, $p = 0.07$). Inspection of the quality indicators that referred more closely related to educational aspects revealed that the overall ECERS-E score was significantly related to growth from the first to the third assessment ($b = 0.15$, $p < 0.05$). ECERS-literacy was not related to growth ($b = 0.08$, $p > 0.05$), but ECERS-mathematics ($b = 0.18$, $p < 0.05$) had the strongest influence on growth of the indicators of process quality examined. Model fit of Models 4a–d was satisfactory; all models explained 38% of variance of the intercept, the amount of explained variance in the slope ranged between 28% and 30%.

3.4. *Does the effect of preschool process quality depend on the amount of time the child has spent in the preschool setting at study entry?*

We expected that children who had spent longer in the preschool setting at study entry would show differences in numeracy related to process quality at the first assessment, whereas children with less preschool experience at study entry would show only small quality-related differences in numeracy. As we controlled for age at assessment in all models, the age at preschool entry provides an indirect measure of the amount of preschool experience at study entry. We therefore tested for interactive effects of age at preschool entry and indicators of process quality. When testing the significance of the interaction terms, we controlled for all predictors used in Model 3 (including age at preschool entry) and the relevant indicator of process quality (ECERS-R, ECERS-E, ECERS-literacy, ECERS-mathematics). Results showed that the interactions ECERS-R × age at preschool entry ($b = 0.19$, $p < 0.01$), ECERS-E × age at preschool entry ($b = 0.16$, $p < 0.05$), and ECERS-mathematics × age at preschool entry ($b = 0.38$, $p < 0.05$) had a significant effect on the intercept. Inclusion of the interaction

Table 3
Results of latent growth curve analyses predicting the development of numeracy skills from the first to the third point of measurement.

Predictors	Model 3				Model 4a				Model 4b			
	Intercept		Slope		Intercept		Slope		Intercept		Slope	
	B	*SE (B)*	*B*	*SE (B)*	*B*	*SE (B)*	*B*	*SE (B)*	*B*	*SE (B)*	*B*	*SE (B)*
Structural preschool characteristics												
Class size	−0.02	0.04	0.08	0.08	−0.02	0.05	0.11	0.07	−0.02	0.04	0.11	0.07
Average age of the class	0.13*	0.05	−0.06	0.08	0.12*	0.05	−0.08	0.08	0.13*	0.05	−0.08	0.08
Child–staff ratio	−0.11*	0.06	−0.12	0.08	−0.11#	0.06	−0.09	0.08	−0.12*	0.06	−0.09	0.08
Proportion of children whose parents had a native language other than German	−0.14#	0.07	−0.04	0.10	−0.13#	0.08	0.01	0.10	−0.14*	0.07	−0.02	0.10
Amount of space (m^2) per child	0.13*	0.05	−0.05	0.08	0.12*	0.05	−0.10	0.07	0.14*	0.05	−0.09	0.07
Federal state	0.21	0.13	0.12	0.19	0.22#	0.13	0.10	0.19	0.23#	0.13	0.03	0.20
Process quality												
ECERS-R					0.02	0.07	0.14#	0.08				
ECERS-E									−0.03	0.06	0.15*	0.07
ECERS-literacy												
ECERS-mathematics												
Slope with intercept	*B* = 0.27		*SE* = 0.19		*B* = 0.27		*SE* = 0.20		*B* = 0.28		*SE* = 0.20	
R^2	0.38*		0.28*		0.38*		0.29*		0.38*		0.29*	
CFI/RMSEA	0.96/0.06				0.96/0.06				0.96/0.06			

Note: The models controlled for all predictors in Model 1 as well as HLE-literacy and HLE-numeracy although not shown in the table. Coefficients were standardized using the variances of the continuous latent variables (Std – standardization).

* $p < 0.05$.

\# $p < 0.10$.

Table 4
Results of latent growth curve analyses predicting the development of numeracy skills from the first to the third point of measurement.

Predictors	Model 4c				Model 4d			
	Intercept		Slope		Intercept		Slope	
	B	*SE (B)*	*B*	*SE (B)*	*B*	*SE (B)*	*B*	*SE (B)*
Structural preschool characteristics								
Class size	−0.02	0.04	0.09	0.08	−0.03	0.04	0.11	0.07
Average age of the class	0.13*	0.05	−0.07	0.08	0.12*	0.05	−0.08	0.08
Child–staff ratio	−0.12*	0.06	−0.10	0.08	−0.11*	0.06	−0.11	0.08
Proportion of children whose parents had a native language other than German	−0.15*	0.07	−0.02	0.10	−0.14$^{\#}$	0.07	−0.01	0.10
Amount of space (m^2) per child	0.13*	0.05	−0.06	0.08	0.13*	0.05	−0.08	0.07
Federal state	0.23$^{\#}$	0.13	0.09	0.20	0.26$^{\#}$	0.13	−0.03	0.20
Process quality								
ECERS-R								
ECERS-E								
ECERS-literacy	−0.04	0.05	0.08	0.07				
ECERS-mathematics					−0.05	0.05	0.18*	0.09
Slope with intercept	*B* = 0.27		*SE* = 0.20		*B* = 0.28		*SE* = 0.20	
R^2	0.38*		0.28*		0.38*		0.30*	
CFI/RMSEA	0.96/0.06				0.96/0.06			

Note: The models controlled for all predictors in Model 1 as well as HLE-literacy and HLE-numeracy although not shown in the table. Coefficients were standardized using the variances of the continuous latent variables (Std – standardization).
* $p < 0.05$.
\# $p < 0.10$.

terms did not change the significance of any of the child, family background or preschool structural characteristics. Neither did it change the significance of ECERS-E, ECERS-literacy, or ECERS-mathematics. However, the effect of ECERS-R on the slope, which just failed to reach the level of statistical significance in Model 4a, became significant ($b = 0.16$, $p < 0.05$) when the interaction term ECERS-R × age at preschool entry was added to the model.

Fig. 2 illustrates the interaction effect using the ECERS-E scores. To disentangle the effects of age at assessment and age at preschool entry, and to facilitate interpretation, we present the relations for the cohort of children aged 42–47 months at the first assessment. This cohort represents 39.5% of the sample. The cohort sample was divided into two groups according to age at preschool entry (median split). Based on the ECERS-E scores, we divided the sample into three groups representing low-, medium-, and high-quality preschool settings. The low-quality and high-quality groups covered the two extreme quartiles of the sample (representing highest and lowest quality). Because of the small number of preschools with ECERS scores above 5, we decided to use a categorization based on sample statistics to illustrate the interactive effect, rather than the conventional categorization as defined by the authors of the instrument (Sylva et al., 2003). Fig. 2 presents average initial numeracy scores for the subgroups. The findings suggest that high process quality as reflected by the ECERS-E score, as opposed to low or medium quality, was already related to higher numeracy skills at the first measurement point. The longer the children had been in the specific preschool at study entry, the more pronounced the effect. In addition, children did not seem to benefit from medium process quality (relative to low quality) until they had spent a certain amount of time in preschool. The significant interaction effects ECERS-mathematics × age at preschool entry and ECERS-R × age at preschool entry reflect similar patterns of results and can be interpreted in the same way.

3.5. Is the effect of preschool process quality the same among children with home learning environments of different qualities?

We next sought to establish whether beneficial effects of preschool process quality depended on the quality of the home learning environment. To this end, we combined the two HLE scales (literacy and numeracy) to one measure representing overall quality of HLE. The interaction ECERS-E × HLE was tested, controlling for all child, family background, and preschool structural factors included Models 1 and 3, overall quality of HLE, and ECERS-E. The interactive effect proved to be significant for the intercept ($b = 0.87$, $p < 0.05$) and for the slope ($b = 1.50$, $p < 0.05$). The addition of the interaction term did not change the significance of any of the effects reported previously. To illustrate the interactive effect, we again divided the sample into three groups, representing low-, medium-, and high-quality HLE. Again, the low-quality and high-quality groups covered the two extreme quartiles of the sample. Fig. 3 shows average numeracy skills at the first and third assessment for the subgroups of children who attended low-, medium-, and high-quality preschool and experienced low-, medium-, and high-quality HLE. It shows that differences in numeracy at the first measurement point seem to be mainly due to differences in HLE, although children with a low-quality HLE did show small quality-related differences. At the third measurement point, average numeracy was higher for all children, but especially for those children exposed to a medium- or high-quality HLE and a high-quality preschool. Children with a medium-quality HLE seemed to benefit particularly from a high-quality preschool. However, Fig. 3 also shows that children with a low-quality HLE did not seem to benefit from the quality of the preschool. These findings suggest that at least medium support at home may be necessary for

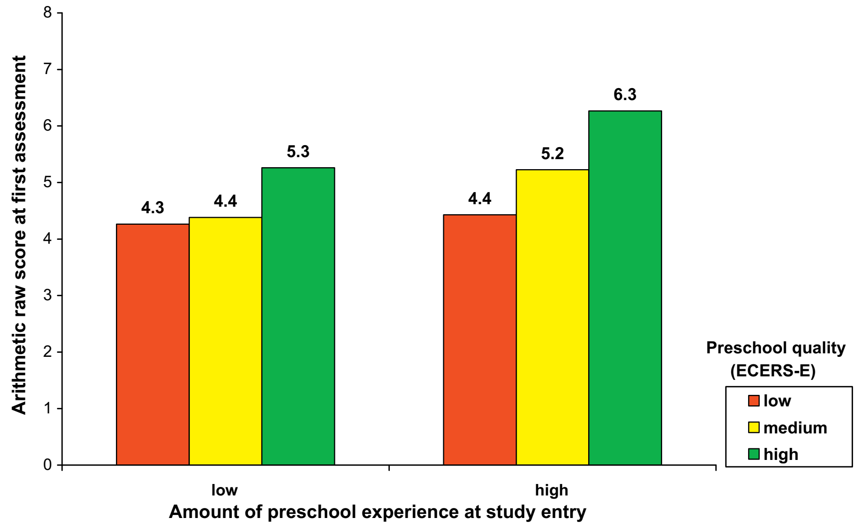

Fig. 2. Influence of preschool quality (ECERS-E) on early numeracy skills for children with different amounts of preschool experience at the first assessment.

children to take advantage of the opportunities for academic learning offered in preschool.

4. Discussion

This study investigated the development of numeracy skills between age 3 and 5 years and provided insights into the possible influences of child and family background factors as well as the home and preschool learning environments in Germany. Findings on child and family background factors revealed that gender, parental native language status, maternal education, and SES were associated with initial numeracy levels as well as with growth. These results replicated the findings of other studies (e.g., ECCE Study Group, 1999; NICHD ECCRN, 2002a; Sammons et al., 2004) and underline that achievement differences due to social and family background emerge very early in children's lives. Both SES and parental native language status independently predicted numeracy skills at age 3. On the one hand, the achievement gap between higher and lower SES children widened over the preschool years. On the other hand, children whose parents had a native language other than German—and especially those children whose parents both had a native language other than German—partly caught up by the age of 5 years. This result is particularly interesting, because recent international student achievement studies have consistently shown that children's cognitive outcomes and educational careers are far more strongly linked to their origin and family background in Germany than in other countries (e.g., OECD, 2004a, 2004b, 2007). As a consequence, expectations regarding the potential benefits of preschool education are especially high for children from disadvantaged or immigrant families. One possible explanation for the finding that children whose parents have a native language other than German seem to catch up over the preschool years is that preschool attendance is preferentially beneficial for this group of children. Unfortunately, the design of the present study does not include a control group without preschool experience; therefore, this possible explanation cannot be further explored within this dataset. It should also to be mentioned that our results are based solely on correlational data and therefore do not allow conclusions on causes and effects to be drawn.

With respect to the quality of stimulation in numeracy and (pre)reading literacy at home, our findings indicate—consistent with other research (e.g., LeFevre et al., 2009; Skwarchuk, 2009)—that families engage in both areas, but that (pre)reading

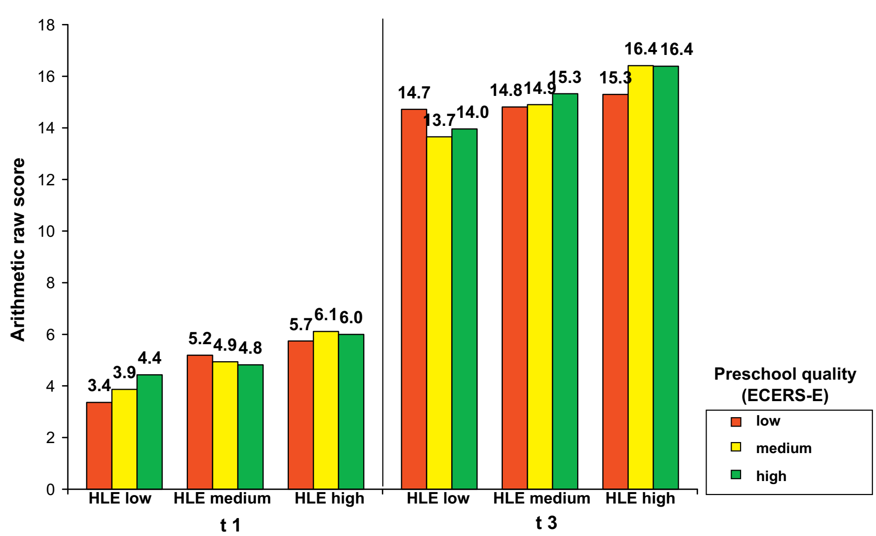

Fig. 3. Influence of preschool quality (ECERS-E) on early numeracy skills at the first and third assessment for children exposed to home learning environments of differing qualities.

literacy-related activities and resources seem to be more prevalent than do numeracy-related activities and resources. Both aspects of the home learning environment were found to have a strong effect on early numeracy skills. Contrary to our expectations, however, the effect was stronger for quality of stimulation in (pre)reading literacy than it was for numeracy. One reason may be that the KABC, like other mathematics tests, requires not only numeracy but also language skills (Abedi & Lord, 2001). It might be argued that adequate language skills are a prerequisite for the acquisition of mathematical knowledge (Aiken, 1972). Therefore, at this early age at which first mathematical concepts are acquired, the quality of the home learning environment to promote verbal literacy may have more impact than its quality to promote numeracy. In addition, we cannot rule out the possibility that the scale measuring quality of home resources and parental activities related to (pre)reading literacy captures more aspects relating to general beneficial characteristics of HLE (e.g., routines) than the numeracy scale does. Another possible explanation is the rarity of numeracy-related resources and parental activities. This argument is in line with results of Blevins-Knabe, Austin, Musun, Eddy, and Jones (2000), who could not replicate the relation between parents' home numeracy activities and children's numeracy outcomes found in an earlier study (Blevins-Knabe & Musun-Miller, 1996) and attributed their finding to the low overall frequency of numeracy-related activities in the later study.

Nevertheless, the present pattern of results highlights the value of a domain-specific concept of the quality of the home learning environment: it demonstrates not only the impact of home environment in stimulating cognitive development, but also the differential effects of the two HLE scales. By the age of 3 years, when children in Germany often experience center-based education and care for the first time, the quality of the home learning environment seems to have shaped their cognitive development and produced strong differences in numeracy skills. It is worth noting that the influence of social background indicators (especially SES) on initial achievement levels is diminished when HLE is included in the model. However, part of the achievement differences related to SES is explained by quality of HLE. This finding is in agreement with the body of research that has consistently shown associations between quality of HLE and socioeconomic indicators (see Bornstein & Bradley, 2008, for an overview; Foster et al., 2005; McCartney, Dearing, Taylor, & Bub, 2007; Melhuish et al., 2008). However, as the effects of social background indicators did not disappear completely, one may conclude that both factors—HLE and social background—have distinct and independent explanatory power for achievement at age 3. In this regard, the findings underline that disadvantaged parents with low SES do not necessarily provide less stimulating learning environments for their children than do parents with higher SES (Sammons et al., 2004). Our analyses show that achievement differences related to quality of HLE that are detectable at the start of preschool are maintained over the preschool years. They do not suggest that the gap between children who grow up in families with low versus high quality of academic stimulation further widens or decreases between the ages of 3 and 5 years. In contrast, previous research has reported that the quality of the early years home learning environment influences not only achievement but also progress over the preschool years (e.g., Sylva et al., 2004). An explanation might be that those studies used less detailed measures of HLE and generally employed other statistical techniques for data analysis that may be less conservative (regression type value-added analyses as opposed to latent growth curve modeling).

With respect to the effect of preschool characteristics on the development of numeracy skills, our data showed that some structural characteristics were related to initial numeracy: Children in classes of higher average age and with better child–staff ratios showed better numeracy skills. Further, the amount of space (m^2) per child was also associated with better baseline numeracy. On the one hand, these associations are plausible, as the characteristics are—in the cases of child–staff ratio and size of the preschool—taken as quality indicators. Additionally, the average age of the class, for example, is related to preschool process quality in terms of promoting academic skills (e.g., Kuger & Kluczniok, 2008). Therefore, these characteristics may also influence achievement levels. What is striking, however, is that these indicators influenced initial achievement, but did not explain variation in the growth of numeracy skills. These characteristics take effect rapidly and were thus—as most of the children had already been in preschool for at least some months when the first assessment took place—already evident at the first assessment. As the models controlled for SES and maternal educational level, it seems unlikely that these effects reflect socioeconomic selection bias. On the other hand, other background variables (e.g., family structure, characteristics of immigrant families) have shown to be significantly related to cognitive outcomes in other studies (e.g., Anme & Segal, 2004). As these variables could not be included in the present analyses, we cannot completely rule out the possibility of selection bias.

The development of numeracy skills was also found to be associated with the process quality of the preschool, with high-quality preschool education also having potentially beneficial effects in Germany. Whereas global quality as conceptualized by the ECERS-R was marginally significantly related to the growth of numeracy skills, the quality of the preschool to promote academic skills as defined by the overall ECERS-E measure had a significant moderate effect on growth. The strongest effect was found for the mathematics subscale, whereas the (pre)reading literacy subscale was not related to the development of numeracy skills. Thus, our results also confirmed the value of investigating domain-specific aspects of preschool education, rather than restricting research to global quality indicators. Two points that may lead to an underestimation of quality-related effects should be taken into account when evaluating the present findings. First, high process quality, especially in terms of aspects that foster children's academic skills, is still rare in German preschools. Accordingly, the variance in preschool process quality was limited at the upper range of the quality scale—both in this sample and in previous studies (e.g., Sylva, 2010). Recent results based on NICHD data further indicate that preschool quality can only be expected to have beneficial effects if it exceeds a certain critical threshold (Burchinal, Vandergrift, Pianta, & Mashburn, 2010). Thus, the chances of detecting effects of preschool quality on children's cognitive development are reduced in the German sample. Second, the results of the interaction analyses showed that numeracy differences at baseline can be partly explained by differences in preschool quality for those children who had already spent a certain amount of time in the preschool setting. If this interaction effect is overlooked in the evaluation of results, the effects of preschool process quality can easily be underestimated. Although relevant to most studies on preschool effects, this possible source of underestimation has to date received little research attention.

Obviously, the quality of the home learning environment seems to be crucial for differences in numeracy skills at preschool entry. The strong influence of parental resources and activities related to verbal literacy points to the possibility that differences in early numeracy skills may also be attributable to differences in language skills or to a generally stimulating environment at home. In turn, the quality of the preschool learning environment shapes the further development of children's skills over the preschool years. It seems that early numeracy skills can be fostered particularly effectively in center-based educational settings even before the start of compulsory schooling. To help create ideal learning environments for children, researchers need to determine whether children who experience different qualities of stimulation at home benefit to the same extent from the quality of the preschool they attend. Our results show that the effects of the two learning environments are not simply additive. Children with a medium- or high-quality HLE seem able to take advantage of a high-quality preschool, whereas children with a low-quality HLE do not seem able to benefit from two years of high-quality stimulation at preschool. On the one hand, this pattern of results is consistent with the idea that learning experiences at preschool must be adequately supported at home to take effect. On the other hand, it raises the question whether the current understanding of the relationship between preschool quality and cognitive development also applies to disadvantaged children. Other studies investigating interactive effects of the preschool and home learning environments have yielded mixed and contradictory results. The NICHD study which was conducted in the United States did not find any interactive effects (NICHD ECCRN, 2003). In contrast, Sammons, Anders, et al. (2008) found in an English sample that children who grew up in poorly stimulating home environments benefited preferentially from highly effective or high-quality preschool education. As such, our results may reveal a pattern specific for Germany.

4.1. Implications for practitioners and policy makers

This study provided evidence for the potential of early education programs to foster numeracy skills before elementary school entry and thus confirmed that recent policy changes in Germany are steps in the right direction. However, preschool education may only be an effective means of promoting the development of cognitive skills if it is of high quality. Hence, our findings emphasize that it is important to make high-quality preschool education accessible for all children. However, we also found evidence for parents' potential to promote the development of their children's early numeracy skills and found that parental support at home seems to be a precondition for academic stimulation at preschool. However, not all parents may know how to best support their children and may need assistance. Intervention studies show that effective parental activities to help children acquire numeracy skills can be trained (Starkey & Klein, 2000). Implementing such parental training programs and improving the partnership between preschools and parents may be an effective means of ensuring that all children can benefit from high-quality stimulation at preschool.

4.2. Limitations and future research

First, the BiKS 3–10 design does not include a control group of children not attending preschool. Consequently, we cannot draw any conclusions regarding the effect of attending versus not attending preschool. Second, BiKS 3–10 is not a birth cohort study, but sampled children at the start of preschool (age 3 years) or later. All assessments of learning environments took place at the age of 3 years at the earliest. Earlier experiences may, of course, also have influenced children's development. In particular, it is important to consider that all HLE measures were assessed during the preschool years. These measures can only approximate the quality of the home learning environment before entry to the study. We found a strong effect of HLE on initial numeracy skills and concluded that this finding demonstrates the influence of HLE on the cognitive development of children before they enter preschool. As other studies have shown that home environments are fairly stable (Son & Morrison, 2010), this assumption seems plausible. Nevertheless, further research is required to confirm this conclusion. Of course, the present data do not allow us to disentangle the covariation between genetic transmission and home environment. Future analyses will compare other approaches to controlling for selection bias with the covariate approach taken in this study. Another notable limitation relates to our outcome measure. Although there were good reasons for choosing the arithmetic subscale of the Kaufman Assessment Battery, some limitations need to be discussed. The scale does not capture all aspects of number sense discussed in the literature (e.g., Griffin, 2004; Jordan et al., 2010; Sarama & Clements, 2009) and nonverbal tasks assessing early arithmetic skills are comparatively rare. The verbal demands of the KABC may partly explain why substantive correlations emerged with SES as well as with pre(reading) literacy stimulation in the home. This finding corresponds with the results of other studies showing that verbal indicators of mathematical skills are highly sensitive to SES (e.g., Jordan, Huttenlocher, & Levine, 1994). However, the results also imply that the KABC is sensitive to early input and instruction and to the influence of the home and preschool learning environment—making it a good choice for the present study (see also Jordan, Levine, & Huttenlocher, 1994). Whereas this article focused on the development of numeracy skills, future research will examine other cognitive domains as well as at social skills and their interrelations. We will also further explore the potential differential effects of preschool experience for different subgroups of children (e.g., children with special needs or special abilities). Finally, future analyses will investigate whether the beneficial effects of high-quality preschool documented in this article diminish or persist when children move on to elementary school.

References

Abedi, J., & Lord, C. (2001). The language factor in mathematics tests. *Applied Measurement in Education*, *14*, 219–234. doi:10.1207/S15324818AME1403_2

Adi-Japha, E., & Klein, P. S. (2009). Relations between parenting quality and cognitive performance of children experiencing varying amounts of childcare. *Child Development*, *80*, 893–906. doi:10.1111/j.1467-8624.2009.01304.x

Aiken, L. R. (1972). Language factors in learning mathematics. *Review of Education Research*, *42*, 359–385. doi:10.2307/1169995

Anders, Y., Sammons, P., Taggart, B., Sylva, K., Melhuish, E., & Siraj-Blatchford, I. (2011). The influence of child, family, home factors and pre-school education on the identification of special educational needs at age 10. *British Educational Research Journal*, *37*, 421–441. doi:10.1080/01411921003725338

Anme, T., & Segal, U. A. (2004). Implications for the development of children in over 11 hours of centre-based care. *Child: Care, Health & Development*, *30*, 345–352. doi:10.1111/j.1365-2214.2004.00429.x

Arbuckle, J. L. (1996). Full information estimation in the presence of incomplete data. In G. A. Marcoulides, & R. E. Schumacker (Eds.), *Advanced structural equation modeling* (pp. 243–277). Mahwah, NJ: Erlbaum.

Belsky, J., Vandell, D., Burchinal, M., Clarke-Stewart, K. A., McCartney, K., Owen, M., et al. (2007). Are there long-term effects of early child care? *Child Development*, *78*, 681–701. doi:10.1111/j.1467-8624.2007.01021.x

Blevins-Knabe, B., Austin, A., Musun, L., Eddy, A., & Jones, R. (2000). Family home care providers' and parents' beliefs and practices concerning mathematics with young children. *Early Child Development and Care*, *165*, 41–58. doi:10.1080/0300443001650104

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting*, *5*, 35–45. doi:10.1002/(SICI)1099-0917(199603)5:1<35::AID-EDP113>3.0.CO;2-0

Blevins-Knabe, B., Whiteside-Mansell, L., & Selig, J. (2007). Parenting and mathematical development. *Academic Exchange Quarterly*, *11*, 76–80.

Bornstein, M. H., & Bradley, R. H. (Eds.). (2008). *Socio-economic status, parenting, and child development*. Mahwah, NJ: Erlbaum.

Bradley, R. H. (2002). Environment and parenting. In M. H. Bornstein (Ed.), *Handbook of parenting, Vol. 2. Biology and ecology of parenting* (pp. 281–314). Mahwah, NJ: Erlbaum.

Brooks-Gunn, J., Han, W.-J., & Waldfogel, J. (2010). First-year maternal employment and child development in the first seven years. *Monographs of the Society for Research in Child Development*, *75*, 1–147. doi:10.1111/j.1540-5834.2010.00562-00574.x

Bryant, D. M., Burchinal, M., Lau, L. B., & Sparling, J. J. (1994). Family and classroom correlates of Head Start children's developmental outcomes. *Early Childhood Research Quarterly*, *9*, 289–304. doi:10.1016/0885-2006(94)90011-6

Burchinal, M. R., Peisner-Feinberg, E. S., Pianta, R., & Howes, C. (2002). Development of academic skills from preschool through second grade: Family and classroom predictors of developmental trajectories. *Journal of School Psychology*, *40*, 415–436. doi:10.1016/S0022-4405(02)00107-3

Burchinal, M., Vandergrift, N., Pianta, R., & Mashburn, A. (2010). Threshold analysis of association between child care quality and child outcomes for low income children in pre-kindergarten programs. *Early Childhood Research Quarterly*, *25*, 166–176. doi:10.1016/j.ecresq.2009.10.004

Caldwell, B., & Bradley, R. (1984). *Home observation for measurement of the environment (HOME)*. Little Rock, AR: University of Arkansas at Little Rock.
Cryer, D., Tietze, W., Burchinal, M., Leal, T., & Palacios, J. (1999). Predicting process quality from structural quality in preschool programs: A cross-country comparison. *Early Childhood Research Quarterly*, *14*, 339–361. doi:10.1016/S0885-2006(99)00017-4
Dornheim, D. (2008). (*Prediction of mathematics literacy and dyscalculia: The impact of prior knowledge of numbers and general cognitive abilities*) *Prädiktion von Rechenleistung und Rechenschwäche: Der Beitrag von Zahlen-Vorwissen und allgemein-kognitiven Fähigkeiten*. Berlin, Germany: Logos.
Dowsett, C. J., Huston, A. C., Imes, A. E., & Genettian, L. (2008). Structural and process features in three types of child care for children from high and low income families. *Early Childhood Research Quarterly*, *23*, 69–93. doi:10.1016/j.ecresq.2007.06.003
Dubowy, M., Ebert, S., von Maurice, J., & Weinert, S. (2008). Sprachlich-kognitive Kompetenzen beim Eintritt in den Kindergart Ein Vergleich von Kindern mit und ohne Migrationshintergrund [Linguistic-cognitive competencies at entry to preschool: A comparison of children with without migration F background]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, *40*, 124–134. doi:10.1026/0049-8637.40.3.124
Early, D. M., Iruka, I. U., Ritchie, S., Barbarin, O. A., Winn, D.-M. C., Crawford, G. M., et al. (2010). How do pre-kindergarteners spend their time? Gender, ethnicity, and income as predictors of experiences in pre-kindergarten classrooms. *Early Childhood Research Quarterly*, *25*, 177–193. doi:10.1016/j.ecresq.2009.10.003
Early, D. M., Maxwell, K. L., Burchinal, M., Alva, S., Bender, R. H., Bryant, D., et al. (2007). Teachers' education, classroom quality, and young children's academic skills: Results from seven studies of preschool programs. *Child Development*, *78*, 558–580. doi:10.1111/j.1467-8624.2007.01014.x
Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal*, *8*, 430–457. doi:10.1207/S15328007SEM0803_5
European Child Care and Education (ECCE) Study Group.Tietze, W., Hundertmark-Mayser, J., & Rossbach, H.-G. (1999). *School-age assessment of child development: Long-term impact of pre-school experiences on school success, and family–school relationships*. Brussels, Belgium: European Union.
Foster, M. A., Lambert, R., & Abbott-Shim, M. (2005). A model of home learning environment and social risk factors in relation to children's emergent literacy and social outcomes. *Early Childhood Research Quarterly*, *1*, 13–36. doi:10.1016/j.ecresq.2005.01.006
Ganzeboom, H. B. G., De Graaf, P. M., & Treiman, D. J. (1992). A standard international socio-economic index of occupational status. *Social Science Research*, *21*(1), 1–56. doi:10.1016/0049-089X(92)90017-B
Gorey, K. M. (2001). Early childhood education. A meta-analytic affirmation of the short- and long-term benefits of educational opportunity. *School Psychology Quarterly*, *16*, 9–30. doi:10.1521/scpq.16.1.9.19163
Graham, J. W., & Hofer, S. M. (2000). Multiple imputation in multivariate research. In T. D. Little, K. U. Schnabel, & J. Baumert (Eds.), *Modeling longitudinal and multilevel data: Practical issues, applied approaches, and specific examples* (pp. 201–218). Mahwah, NJ: Erlbaum.
Griffin, S. (2004). Building number sense with number worlds: A mathematics program for young children. *Early Childhood Research Quarterly*, *19*, 173–180. doi:10.1016/j.ecresq.2004.01.012
Griffin, E., & Morrison, F. (1997). The unique contribution of home literacy environment to difference in early literacy skills. *Early Child Development and Care*, *127*, 233–243. doi:10.1080/0300443971270119
Harms, T., Clifford, R. M., & Cryer, D. (1998). *Early childhood environment rating scale* (Rev. ed.). New York, NY: Teachers College Press.
Hart, B., & Risley, R. T. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Brookes.
Heckman, J. J. (2006). Skill formation and the economics of investing in disadvantaged children. *Science*, *312*, 1900–1902. doi:10.1126/science 1128898
Hu, L.-T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*, 1–55. doi:10.1080/10705519909540118
Jacobs, J. E., Davis-Kean, P., Bleeker, M., Eccles, J. S., & Malanchuk, O. (2005). I can, but I don't want to: The impact of parents, interests and activities on gender differences in math. In A. Gallagher, & J. Kaufman (Eds.), *Gender differences in mathematics* (pp. 246–263). New York, NY: Cambridge University Press.
Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences*, *20*, 82–88. doi:10.1016/j.lindif.2009.07.004
Jordan, N. C, Huttenlocher, J., & Levine, S. C. (1994). Assessing early arithmetic abilities: Effects of verbal and nonverbal response types on the calculation performance of middle- and low-income children. *Learning and Individual Differences*, *6*, 413–432. doi:10.1016/1041-6080(94)90003-5
Jordan, N. C., Levine, S. C., & Huttenlocher, J. (1994). Development of calculation abilities in middle- and low-income children after formal instruction in school. *Journal of Applied Developmental Psychology*, *15*, 223–240. doi:10.1016/0193-3973(94)90014-0
Knudsen, E. J., Heckman, J. J., Cameron, J. L., & Shonkoff, J. P. (2006). Economic, neurobiological and behavioral perspectives on building America's future workforce. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(27), 10155–10162. doi:10.1073/pnas.0600888103
Kuger, S., & Kluczniok, K. (2008). Prozessqualität im Kindergarten. Konzept, Umsetzung und Befunde [Process quality in preschools: Concept, implementation, and findings]. *Zeitschrift für Erziehungswissenschaft, Sonderheft*, *11*, 159–178. doi:10.1007/978-3-531-91452-7_11
Kuger, S., Pflieger, K., & Rossbach, H.-G. (2005). *Familieneinschätzskala Forschungsversion [Family rating scale, research version]*. Unpublished instrument, University of Bamberg, Bamberg, Germany.
LeFevre, J., Clarke, T., & Stringer, A. (2002). Influences of language and parental involvement on the development of counting skills: Comparisons of French- and English-speaking Canadian children. *Early Child Development and Care*, *172*, 283–300. doi:10.1037/a0014532
LeFevre, J., 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*, *41*, 55–66. doi:10.1080/03004430212127
Leseman, P. P. M., Scheele, A. F., Mayo, A. Y., & Messer, M. H. (2007). Home literacy as a special language environment to prepare children for school. *Zeitschrift für Erziehungswissenschaft*, *10*, 334–355. doi:10.1007/s11618-007-0040-9
Little, R. J. A., & Rubin, D. B. (1987). *Statistical analysis with missing data*. New York, NY: Wiley.
Magnuson, K., Meyers, M., Ruhm, R., & Waldfogel, J. (2004). Inequality in preschool education and school readiness. *American Educational Research Journal*, *41*, 115–157. doi:10.3102/00028312041001115
McCartney, K., Dearing, E., Taylor, B. A., & Bub, K. L. (2007). Quality child care supports the achievement of low-income children Direct indirect effects via caregiving the home F environment. *Journal of Applied Developmental Psychology*, *28*, 411–426. doi:10.1016/j.appdev.2007.06.010
Melchers, P., & Preuss, U. (2003). *Kaufman Assessment Battery for Children (KABC). German Version* (6th ed.). Göttingen, Germany: Hogrefe.
Melhuish, E. (2010). Why children parents and home learning are important. In K. Sylva, E. Melhuish, P. Sammons, I. Siraj-Blatchford, & B. Taggart (Eds.), *Early childhood matters. Evidence from the Effective Pre-school and Primary Education project* (pp. 44–59). Abingdon, NY: Routledge.
Melhuish, E., Sylva, K., Sammons, P., Siraj-Blatchford, I., Taggart, B., & Phan, M. (2008). Effects of home learning environment and preschool center experience upon literacy and numeracy in early primary school. *Journal of Social Issues*, *64*, 95–114. doi:10.1111/j.1540-4560.2008.00550.x
Muthén, L. K., & Muthén, B. O. (2008). *MPlus user's guide* (5th ed.). Los Angeles, CA: Muthén & Muthén.
Neuman, S. B., Copple, C., & Bredekamp, S. (2000). *Learning to read and write: Developmentally appropriate practices for young children*. Washington, DC: National Association for the Education of Young Children.
NICHD ECCRN. (2002a). Early child care and children's development prior to school entry. Results from the NICHD Study of Early Child Care. *American Educational Research Journal*, *39*, 133–164. doi:10.3102/00028312039001133
NICHD ECCRN. (2002b). Child-care structure-process-outcome: Direct and indirect effects of child care quality on young children's development. *Psychological Science*, *13*, 199–206. doi:10.1111/1467-9280.00438
NICHD ECCRN. (2003). Does quality of child care affect child outcomes at age 4½? *Developmental Psychology*, *39*, 451–469. doi:10.1037/0012-1649.39.3.451
NICHD ECCRN. (2005). Early child care and children's development in the primary grades. Follow-up results from the NICHD Study of Early Child Care. *American Educational Research Journal*, *42*, 537–570. doi:10.3102/00028312042003537
NICHD ECCRN. (2006). Child-care effect sizes for the NICHD Study of Early Child Care and Youth Development. *American Psychologist*, *61*, 99–116. doi:10.1037/0003-066X.61.2.99
NICHD ECCRN, & Duncan, G. J. (2003). Modeling the impacts of child care quality on children's preschool cognitive development. *Child Development*, *74*, 1454–1475. doi:10.1111/1467-8624.00617
OECD. (2004a). *Learning for tomorrow's world. First results from PISA 2003*. Paris, France: OECD.
OECD. (2004b). *Messages from PISA 2000*. Retrieved from http://www.pisa.oecd.org/dataoecd/31/19/34107978.pdf
OECD. (2007). *PISA 2006: Science competencies for tomorrow's world*. Paris, France: OECD.
Peisner-Feinberg, E. S., Burchinal, M. R., Clifford, R. M., Culkin, M. L., Howes, C., Kagan, S. L., et al. (2001). The relation of preschool child-care quality to children's cognitive and social developmental trajectories through second grade. *Child Development*, *72*, 1534–1553. doi:10.1111/1467-8624.00364
Pianta, R. C., Howes, C., Burchinal, M., Bryant, D., Clifford, D., Early, D., et al. (2005). Features of pre-kindergarten programs, classrooms, and teachers: Do they predict observed classroom quality and child–teacher interactions? *Applied Developmental Science*, *9*, 144–159. doi:10.1207/s1532480xads0903_2
Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. London, UK: Sage.
Rossbach, H.-G., Kluczniok, K., & Kuger, S. (2008). Auswirkungen eines Kindergartenbesuchs auf den kognitiv-leistungsbezogenen Entwicklungsstand von Kindern [The effects of attending kindergarten on children's cognitive and performance-related development]. *Zeitschrift für Erziehungswissenschaft, Sonderheft*, *11*, 139–158. doi:10.1007/978-3-531-91452-7_10
Rossbach, H.-G., & Tietze, W. (2007). *Kindergarten-Skala. Erweiterung KES-E [German version of The Early Childhood Environment Rating Scale: Extension ECERS-E]*. Unpublished instrument, University of Bamberg, Bamberg, Germany.
Sammons, P., Anders, Y., Sylva, K., Melhuish, E., Siraj-Blatchford, I., Taggart, B., et al. (2008). Children's cognitive attainment and progress in English primary schools during Key Stage 2. Investigating the potential continuing influences of preschool education. *Zeitschrift für Erziehungswissenschaft, Sonderheft*, *11*, 179–198. doi:10.1007/978-3-531-91452-7_12

Sammons, P., Elliot, K., Sylva, K., Melhuish, E., Siraj-Blatchford, I., & Taggart, B. (2004). The impact of pre-school on young children's cognitive attainment at entry to reception. *British Educational Research Journal*, *30*, 691–712. doi:10.1080/0141192042000234656

Sammons, P., Sylva, K., Melhuish, E., Siraj-Blatchford, I., Taggart, B., & Hunt, S. (2008). *The Effective Pre-School and Primary Education 3-11 Project (EPPE 3-11): Influences on children's attainment and progress in Key Stage 2: Cognitive outcomes in year 6*. Research Report DCSF-RR048. DfE/Institute of Education, University of London. Retrieved from http://eppe.ioe.ac.uk/eppe3-11/eppe3-11%20pdfs/eppepapers/DfE-RR048.pdf

Sarama, J., & Clements, D. H. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. New York, NY: Routledge.

Schmidt, S., Schmitt, M., & Smidt, W. (2009). (*The BiKS Study: Methodological report, 2nd project phase*) *Die BiKS-Studie. Methodenbericht zur zweiten Projektphase*. Retrieved from http://psydok.sulb.uni-saarland.de/volltexte/2009/2534/

Sirin, S. R. (2005). Socio-economic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*, 417–453. doi:10.3102/00346543075003417

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

Snow, C., & Van Hemel, S. (2008). *Early childhood assessment: Why what and how? Report of the Committee on Developmental Outcomes and Assessments for Young Children*. Washington, DC: National Academies Press.

Son, S.-H., & Morrison, F. J. (2010). The nature and impact of changes in the home learning environment on growth of language and academic skills of preschool children. *Developmental Psychology*, *46*, 1103–1118. doi:10.1037/a0020065

Starkey, P., & Klein, A. (2000). Fostering parental support for children's mathematical development: An intervention with Head Start families. *Early Education and Development*, *11*, 659–680. doi:10.1207/s15566935eed1105_7

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly*, *19*, 99–120. doi:10.1016/j.ecresq.2004.01.002

Sylva, K. (2010). Quality in early childhood settings. In K. Sylva, E. Melhuish, P. Sammons, I. Siraj-Blatchford, & B. Taggart (Eds.), *Early childhood matters. Evidence from the Effective Pre-school and Primary Education project* (pp. 70–91). Abingdon, NY: Routledge.

Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2004). *The Effective Provision of Pre-school Education project (EPPE): Technical Paper 12. The Final Report*. London, UK: Institute of Education, University of London.

Sylva, K., Siraj-Blatchford, I., & Taggart, B. (2003). *Assessing quality in the Early Childhood Rating Scale Extensions (ECERS-E)*. Stoke On Trent, UK: Trentham Books.

Taylor, L., Clayton, J., & Rowley, S. (2004). Academic socialization: Understanding parental influences on children's school-related development in the early years. *Review of General Psychology*, *8*, 163–178. doi:10.1037/1089-2680.8.3.163

Tietze, W., Meischner, T., Gänsfuß, R., Grenner, K., Schuster, K.-M., Völkel, P., et al. (1998). (*How good are our preschools? A study on the educational quality of German preschools*) *Wie gut sind unsere Kindergärten? Eine Untersuchung zur pädagogischen Qualität in deutschen Kindergärten*. Neuwied, Germany: Luchterhand.

Tietze, W., Rossbach, H.-G., & Grenner, K. (2005). (*Children from age 4 to 8 years. Quality of the educational settings preschool, primary school and family*) *Kinder von 4 bis 8 Jahren. Zur Qualität der Erziehungs- und Bildungsinstitution Kindergarten Grundschule und Familie*. Weinheim, Germany: Beltz.

Tietze, W., Schuster, K.-M., Grenner, K., & Rossbach, H.-G. (2007). (*German version of the Early Childhood Environment Rating Scale. Revised Edition*) *Kindergarten-Skala Revidierte Fassung (KES-R)*. Weinheim, Germany: Beltz.

Totsika, V., & Sylva, K. (2004). The Home Observation for Measurement of the Environment revisited. *Child and Adolescent Mental Health*, *9*, 25–35. doi:10.1046/j.1475-357X.2003.00073.x

Tudge, J., & Doucet, F. (2004). Everyday mathematical experiences: Observing young Black and White children's everyday activities. *Early Childhood Research Quarterly*, *19*, 21–39. doi:10.1016/j.ecresq.2004.01.007

Tymms, P., Merell, C., & Henderson, B. (1997). The first year at school: A quantitative investigation of the attainment and progress of pupils. *Educational Research and Evaluation*, *3*, 101–118. doi:10.1080/1380361970030201

Vandell, D., Belsky, J., Burchinal, M., Steinberg, L., Vandergrift, N., & the NICHD Early Child Care Research Network. (2010). Do effects of early child care extend to age 15 years? Results from the NICHD Study of Early Child Care and Youth Development. *Child Development*, *81*, 737–756. doi:10.1111/j.1467-8624.2010.01431.x

von Maurice, J., Artelt, C., Blossfeld, H.-P., Faust, G., Rossbach, H.-G., & Weinert, S. (2007). (*Educational processes, competence development and selection decisions at pre- and primary school age: Overview of data collection in the first two years of the longitudinal studies BiKS-3-8 and BiKS-8-12*) *Bildungsprozesse. Kompetenzentwicklung und Formation von Selektionsentscheidungen im Vor- und Grundschulalter. Überblick über die Erhebung in den Längsschnitten BiKS-3-8 und BiKS-8-12 in den ersten beiden Projektjahren*. Retrieved from http://psydok.sulb.uni-saarland.de/volltexte/2007/1008

Weinert, S., Ebert, S., & Dubowy, M. (2010). Kompetenzen und soziale Disparitäten im Vorschulalter [Competencies and social disparities at preschool age]. *Zeitschrift für Grundschulforschung*, *1*, 32–45.

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, *69*, 848–872. doi:10.1111/j.1467-8624.1998.00848.x