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Longitudinal Associations between Teacher–Child Interactions in Kindergarten and

Academic Skills in Elementary School

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Abstract

This study examined the extent to which the quality of teacher–child interactions assessed in kindergarten (6-year-olds) is associated with children's reading and math development across the elementary school years. The sample consisted of 515 Finnish children (271 boys, 244 girls). Teacher–child interactions were observed in 49 kindergarten classrooms. The findings from the latent growth curve models showed that high-quality teacher–child interactions in kindergarten were positively associated with the initial levels of reading and math skills. Furthermore, the results indicated that high-quality teacher–child interactions in kindergarten were positively associated with children's academic skills four years later. The results emphasize the importance of strong emotional, organizational, and instructional supports in kindergarten for further development of academic skills.

Keywords: teacher–child interactions; kindergarten; academic skills; long-term associations

Longitudinal Associations between Teacher–Child Interaction in Kindergarten and

Academic Skills in Elementary School

Given the increasing participation and policy interest in early education programs, the long-term benefits of early childhood education are of interest worldwide. In the United States in particular, the efficiency of teaching and early education programs as a means of reducing gaps in academic performance has been the focus of numerous studies (e.g., Burchinal et al., 2008; Vandell, Belsky, Burchinal, Vandergrift, & Steinberg, 2010). Recent research has proposed that the process quality of classrooms, that is, teacher–child interactions, is more influential than participation in program and the structural features of programs (Mashburn et al., 2008; see also Yoshikawa et al., 2013). However, few studies outside the United States have investigated the long-term benefits of preschool and kindergarten process quality (see Anders, Grosse, Rossbach, Ebert, & Weinert, 2013; Lehr, Kluczniok, & Rossbach, 2016; Sylva, Melhuish, Sammons, Siraj-Blatchford, & Taggart, 2008), and none of them has used the Classroom Assessment Scoring System (CLASS). The major benefits of CLASS instruments are that it provides a theoretically grounded and an empirically tested tool for investigating teacher–child interactions in a variety of cultural and educational settings, it has been widely used in US settings, and it produces scores for three domains of teacher–child interactions of particular importance for child development. Consequently, the present study builds on prior research by examining whether the observed quality of teacher–child interactions in kindergarten classrooms (6-year-olds) is associated with Finnish children's development of reading and math skills across their elementary school years. The current study adds to the literature by investigating the long-term predictive role of teacher–child interactions for both initial level and further development of reading and math skills by conducting a five-year follow-up from kindergarten to Grade 4, by taking into account several important control factors, and by using advanced statistical methods.

Quality of Teacher–child interactions as a Predictor of Academic Skills

The key aspects of quality in preschool education are stimulating and supportive interactions between teachers and children (e.g., Yoshikawa et al. 2013; see also Mashburn et al., 2008). In their Teaching Through Interactions (TTI) framework, Hamre et al. (2013, 2014) conceptualized the quality of teacher–child interactions in three broad domains: emotional support, classroom organization, and instructional support. *Emotional support* refers to a positive tone in interactions and a warm and supportive climate in a classroom. Emotionally supportive teachers are sensitive and responsive to children's needs, and provide children with appropriate levels of leadership and autonomy (Pianta, La Paro, & Hamre, 2008). *Classroom organization* consists of effective teacher management of time and attention and setting of clear rules and routines (Yates & Yates, 1990). In addition to providing a structure for learning, teachers with high classroom organization skills also actively monitor the classroom and try to keep children engaged in academic activities (Pianta, La Paro et al., 2008). *Instructional support* captures the quality of the teacher's feedback, stimulation of thinking skills and reasoning in the classroom, and explicit linking of content knowledge with meaningful contexts (Hamre et al., 2013; Pianta, La Paro et al., 2008).

Many theoretical perspectives support the view that teacher–child interactions influence child outcomes. The ecological systems theory argues that the interactions that take place among teachers and students on a daily basis (i.e., proximal processes) are the key mechanisms through which children learn (Bronfenbrenner & Morris, 2006). Attachment theory (see Bergin & Bergin, 2009) posits that if children feel emotionally secure and respected by their teachers, they are better able to invest their attention and engagement in learning (Pianta, 1999). Self-determination theory (SDT; Ryan & Deci, 2000) contends that students' engagement in learning activities and subsequent schooling outcomes are enhanced

if the basic psychological need for autonomy, relatedness, and competence are met in a classroom. Within the TTI framework, teachers can promote these needs, for example, by being sensitive to students' needs, by being responsive, by taking children's initiatives into account, and by providing process-oriented feedback (Hamre et al., 2013). Furthermore, empirical findings concerning environmental support for the development of children's self-regulatory skills (Paris & Paris, 2001; Raver et al., 2009), and cognitive and linguistic skills (Wharton-McDonald, Pressley, & Mistretta-Hampston, 1998) indicate that there is positive association between instructional and organizational supports and child outcomes. For example, teachers who provide high-quality instructional support give children rich learning opportunities by scaffolding, extending, and providing consistent, process-oriented feedback (Hamre et al., 2014; Pianta, La Paro et al., 2008), which in turn contributes to children's skill development (Mashburn et al., 2008). In addition, well-organized activities and proactive behavior management contribute to better self-regulatory skills in children (Cadima et al., 2015; Rimm-Kaufman et al., 2009; Hamre et al., 2013), which then translate into better academic skills (Ponitz, Rimm-Kaufman, Brock, & Nathanson, 2009).

Longitudinal Effects of Teacher–Child Interactions

Although the domains of teacher–child interactions are moderately or highly correlated, recent studies have provided evidence of the domain-specific associations of emotional support, classroom organization, and instructional support with child outcomes (e.g., Downer, Sabol, & Hamre, 2010; Hamre et al., 2014). Emotional support has been linked mostly with gains in literacy outcomes. For example, it has been found to predict gains in expressive and receptive language during preschool (Burchinal, Vandegrift, Pianta, & Mashburn, 2010), kindergarten (Curby, Rimm-Kaufman, & Ponitz, 2009) and Grade 1 (Cadima et al., 2010; Curby, Rimm-Kaufman, & Ponitz, 2009; Lee & Bierman, 2015). McDonald-Connor et al. (2005) demonstrated that children who experienced more responsive

teacher–child interactions in preschool showed stronger vocabulary and decoding skills at the end of first grade. Moreover, high levels of emotional support over time and across grades have been associated with progress in reading from preschool to fifth grade (Pianta, Belsky, et al., 2008). There is at least one study showing the beneficial effect of emotional support for math skills: Stronger emotional support in fifth-grade classrooms predicted improved math skills in fifth grade (Pianta, Belsky, et al., 2008).

Research has documented the beneficial effect of classroom organization for both math and literacy outcomes. For instance, high-quality classroom organization has been shown to be related to first graders' print concepts, vocabulary (Cadima et al., 2010), and literacy gains (Ponitz, Rimm-Kaufman, Brock, & Nathanson, 2009). In addition, students with low preschool skills showed greater improvement in number identification skills in first grade when being in classrooms of better classroom organization (Cadima et al., 2010). In a similar vein, Curby et al. (2009) showed that lower-achieving children in classrooms had better kindergarten classroom organization showed greater progression in mathematics across the Grade 1 year.

Previous studies have demonstrated the predictive effect of instructional support mainly for literacy outcomes. High-quality instructional support in preschool has been found to contribute to children's pre-literacy skills (Hamre et al., 2014; Mashburn et al., 2008), their progress in word reading (Curby et al., 2009), and also to their skills in solving applied math problems (Mashburn et al., 2008). Hamre et al. (2014) showed recently that children who had preschool teachers who provided high-quality instructional support made the most gains in early literacy and language skills during their year of preschool. In kindergarten, instructional support is related to better pre-reading skills, such as vocabulary, understanding and the use of spoken language, phonological awareness, and letter knowledge (Burchinal et al., 2008;

Mashburn et al., 2008). Instructional support has also been shown to be linked to children's gains in vocabulary and print concepts in elementary school (Cadima et al., 2010).

Although most of the studies investigating the longitudinal associations between teacher–child interactions and academic outcomes has been conducted in the US classrooms, there are also some studies conducted in Europe. These studies have typically used the Early Childhood Education Rating Scale (ECERS) instrument for measuring the process quality of classrooms (see Cadima et al., 2010 as an exception), which somewhat differs from the process quality measured by CLASS. In a German sample, Anders and colleagues (2012) demonstrated that the preschool process quality in terms of mathematics was related to the progression in children's early numeracy skills between age 3 and 5 years. Lehr et al. (2016) indicated that preschool quality in terms of mathematical stimulation was predictive of growth in mathematical skills between Grades 1 and 3 in a German sample. The findings of the Effective Provision of Preschool Education (EPPE) study (Sylva et al., 2008) in the UK showed that the beneficial effects of high-quality preschool education can last up to the end of primary school and tend to be most beneficial for boys and children from disadvantaged backgrounds.

Previous studies on longitudinal associations have some limitations. Most of the studies using CLASS to date have been conducted in US preschool and kindergarten classrooms, whereas less is known about the associations between teacher–child interactions and child outcomes in other cultural and educational settings. Another limitation is the inconsistency between previous studies with regard to how long the influence of quality of teacher–child interactions lasts. Most of the long-term associations have been reported between preschool center quality and academic outcomes at kindergarten or school entry (1–2 years). However, there are a few longitudinal studies that have investigated whether the quality of preschool or kindergarten teacher–child interactions would predict children's

elementary school outcomes (see Belsky et al., 2007, Pianta, Belsky et al., 2008; Lee & Bierman, 2015 and Vandell et al., 2010 as exceptions). Consequently, further investigation of the long-term associations between the quality of preschool and kindergarten teacher–child interactions and children's academic outcomes is clearly needed. In addition, previous studies differ in the way they have investigated long-term associations between quality of teacher–child interactions and academic skills, i.e., whether they have investigated the academic skills at certain time point (e.g., skills at the beginning of Grade 1) or development of academic skills (e.g., progress during Grades 1–4). Yet another limitation is most of the studies in the field have been conducted in preschool and kindergarten classrooms, whereas less is known about the associations between teacher–child interactions and child outcomes in elementary school. Consequently, the present study adds to the literature by investigating long-term associations (with a five-year follow-up) between teacher–child interactions in kindergarten and children's academic skills in elementary school, using advanced methodology (by investigating the initial level of and growth of fluency as well as more advanced skills).

Research Questions

The present study examined the longitudinal associations between the quality of teacher–child interactions in kindergarten and academic skills in elementary school. The research questions were as follows.

(1) To what extent is the quality of teacher–child interactions (i.e., emotional support, classroom organization, and instructional support) in kindergarten associated with the initial level of and growth of reading and math skills in elementary school (Grades 1–4) when pre-academic skills, nonverbal reasoning, maternal teaching of reading and mathematics, shared reading, and maternal level of education are controlled for? Based on the previous literature, we expected that teacher–child interactions would be positively related to the initial level of (Hypothesis 1a: Hamre et al., 2014; Mashburn et al., 2008) and growth of (Hypothesis 1b:

Anders et al., 2012; 2013; Curby et al., 2009; Lehrl et al., 2016; Pianta, Belsky et al., 2008)

reading and math skills.

(2) To what extent is the quality of teacher–child interactions in kindergarten

associated with reading (i.e., reading fluency and reading comprehension) and math skills

(i.e., arithmetic fluency, arithmetic reasoning, and multiplication) in Grade 4 when pre-

academic skills, nonverbal reasoning, maternal teaching of reading and mathematics, shared

reading, and maternal level of education are controlled for? We expected (Hypothesis 2) that

high-quality teacher–child interactions in kindergarten would be positively associated with

reading and math skills in Grade 4 (e.g., Belsky et al., 2007; Curby et al., 2009; Hamre et al.,

2014; Peisner-Feinberg, 2001; Vandell et al., 2010).

Method

Finnish Kindergarten Education

In Finland, compulsory education begins in the year in which the child turns 7 years of

age and lasts for 9 years. Kindergarten education of 1 year is provided at the age of 6 in the

year preceding entry into elementary school. Providing a place in kindergarten education free

of charge for all children (700 hours per year) is a statutory duty of municipalities in Finland.

Kindergarten education is organized at day care centers (79%) or elementary schools (21%;

Statistics Finland, 2012) according to the guidelines of the National Core Curriculum for Pre-

primary Education (2000, 2010). The goals set for education are based on a holistic view of

the child's growth, development, and lifelong learning. The kindergarten curriculum includes

various content areas (Language and Interaction, Mathematics, Environmental Studies and

Natural Science, Ethics, Health, Physical and Motor Development, and Art and Culture), but

the instruction is not divided into lessons. Learning in the content areas is integrated in

thematic learning activities and play throughout the day. Children's skill development,

positive self-concept, and social skills are promoted through play-related methods and child-

initiated and small-group activities (Hytönen et al., 2003). The assumption is that children learn at their own speed in accordance with their own capabilities and interests under the support of educators.

Although all Finnish kindergarten classrooms follow the same national guidelines, unit-specific curricula are developed in individual early childhood education and care settings and teachers are granted a great amount of autonomy. According to the core curriculum, the role of kindergarten education is to provide all children with an equal opportunity to learn the basic skills needed for elementary school, while supporting the children's own interests and motivation for learning, but without formal instruction. Although the Finnish educational system is renowned for providing equal access to high-quality education and successful learning outcomes, no empirical study has investigated the longitudinal associations between the process quality of kindergarten classrooms and academic skills across elementary school years. The present study aimed to investigate whether variations in the quality of teacher–child interactions and long-term effects can be documented in highly homogenous educational contexts, such as in Finland.

Participants

Children and mothers. The present study is part of an extensive cohort study of kindergarten to Grade 4 (Lerkkanen et al., 2006-2016) comprising a total of 1,268 children from three municipalities, two of them located in Central Finland and one in Eastern Finland. The sample of the present study represents a subsample of the original sample and consists of 515 children (271 boys, 244 girls) from observed kindergarten classrooms. The mean age of the children was 80.58 months ($SD = 3.40$ months) at the end of the kindergarten year, and 99% of the children were Finnish-speaking. Parents were asked for written consent for their child's and their own participation in the study. The vast majority of the children, 80%, came from two-parent households, 10% were from single-parent families, 8% were from blended

families, and 2% were from families of divorced parents and had two homes. The sample was representative of the Finnish population in terms of family structure, maternal education, socio-economic background and ethnicity (Statistics Finland, 2012).

Four-hundred and forty-six mothers (85.4%) filled in questionnaires regarding background information. The highest socio-economic background in the family was higher white-collar in 36% of families, lower white-collar in 44.3% of the families, entrepreneurs in 9.2% of the families, workers in 9.9% of the families, and students, pensioners etc in .06% of the families.

Teachers and classrooms in kindergarten. Of the total 137 kindergarten teachers participating in the larger study, 49 teachers (47 women, 2 men) were selected for classroom observations on a voluntary basis. Teachers were asked to provide their written consent before the observation of teacher–child interactions. All of the teachers were qualified to work as kindergarten teachers and had at least a tertiary-level (college) qualification. Their work experience in day care settings ranged from less than a year to more than 15 years (*Mode* = more than 15 years). All the kindergarten classrooms were Finnish-speaking. Although the majority of classrooms consisted of only kindergarten–age children (6-year-olds), the age composition was wider in some of the classrooms. Some groups that were located in day care centers also enrolled younger children (most often 5-year-olds), and some groups that were located in elementary schools also enrolled first and/or second graders Thirty-six classrooms (73.5%) were in day care centers and 13 (26.5%) in elementary schools. Class size ranged from 3 to 24 children (*M* = 13.85; *SD* = 5.92). Typical teacher-to-child-ratio in Finnish kindergartens 1:13 (there can be 20 children in a group if there is also another adult with a proper education). Around 11 (statistically *M* = 10.89, *SD* = 3.35) children were present during an observation session.

Procedure and Measures in Kindergarten

The children's performance on pre-reading and pre-math tests was assessed at the beginning of their kindergarten year (September 2006) and on a nonverbal reasoning test at the end of their kindergarten year (April 2007). All tests were administered by trained testers in individual test situations during the kindergarten class hours. Classroom observations of teacher–child interactions were conducted in live situations on two separate days in the spring of the kindergarten year (February–April 2007). Mothers were asked to fill out questionnaires in the spring of the kindergarten year concerning their reading- and math-related activities with their children at home.

Teacher–child interactions. The kindergarten classrooms were observed using the CLASS Pre-K observation instrument (Pianta; La Paro et al., 2008). The CLASS-Pre-K was chosen because the content and the structure of Finnish kindergarten classrooms most mirror American pre-K as children are not yet provided with formal instruction in reading and mathematics. The CLASS consists of 10 dimensions that measure three domains of teacher–child interactions: (a) Emotional Support (four dimensions: Positive Climate, Negative Climate, Teacher Sensitivity, Regard for Student Perspectives), (b) Classroom Organization (three dimensions: Behavior Management, Productivity, Instructional Learning Formats), and (c) Instructional Support (three dimensions: Concept Development, Language Modeling, Quality of Feedback). Each dimension was rated on a 7-point scale: 1, 2 = *low*, 3–5 = *moderate*, and 6, 7 = *high*. Based on the validation study in Finnish kindergartens, the dimension measuring negative climate was omitted from further analyses (Pakarinen et al., 2010). Because the domains correlated so highly with each other (*r*s ranging from .79 to .89), in the present study we used a composite score of teacher–child interactions, that is, a mean score of Emotional Support, Classroom Organization, and Instructional Support.

The 17 observers were carefully trained and they had to reach 80% agreement before conducting the observations. The first training session (4 h) consisted of an introduction to the CLASS, and overall guidelines for making observations and scoring. The observers were asked to read the manual carefully, beforehand. In the second training session (3 h), a 30-min video recording of a kindergarten classroom was watched and scored independently. The independent ratings made regarding the video used for practice, were compared and discrepancies discussed. Next, the observers went in pairs to conduct their practice coding (3 h) in three kindergarten classrooms which were not participating in the study. After the practice coding sessions, the observers' inter-rater reliability in the level of dimensions and domains was calculated (correlations, differences between observers). Ratings of the two observers that did not differ by more than 1 point (1 SD) were considered to reflect an acceptable degree of accuracy (see Pianta, La Paro et al., 2008). On two occasions out of 17, the discrepancies between the codings were greater than one point. For these two observers, additional classroom scoring practice was required and a meeting was arranged to monitor their subsequent inter-rater agreement.

The observations began in the morning when the instructional activity started (about 9 a.m.) and lasted approximately 3 hours (up to naptime in full-day programs and up to the time the children left in half-day programs). The observations were completed in 30-min cycles so that observers first observed a 20-min period while making notes on behavioral indicators, and in the subsequent 10-min period (before beginning the next observation cycle), they recorded their coding on the scoring sheet. The number of CLASS observation cycles ranged from 4 to 6 ($M = 5.10$, $SD = 0.54$). For each item, the ratings were averaged across all cycles.

Two observers were always present who rated their observations independently. The interrater reliabilities (intraclass correlations, ICCs) between the pairs of observers varied between .80 and .96 (except .63 for Concept Development and .76 for Language Modeling).

For the final analyses, a mean score for each dimension was calculated from the ratings of the two observers. The two observation days were typically 8 days (but less than two weeks) apart (M = 8.14; SD = 10.39; range = 1–50). Correlations between the CLASS ratings for the two separate observation days ranged from .44 (Productivity) to .80 (Teacher Sensitivity). The correlations between the two days were: .76 for Emotional support, .67 for Classroom organization, and .66 for Instructional Support. For the further analyses, the ratings from these two observation days were collapsed.

Control variables. Other factors have also been shown to be associated with academic skills, and were, therefore, controlled for in the analyses. Pre-reading skills (phoneme identification and letter knowledge; Torppa et al., 2007) and pre-math skills (number sequences; Zhang et al., 2014) have been shown to be strong predictors of subsequent academic skills. In addition, general ability has been shown to be linked with reading skills (e.g., Ferrer, Shaywitz, Holahan, Marchione, & Shaywitz, 2010). In this study, we used nonverbal reasoning as a measure of general ability. Maternal education has also been found to be a strong indicator of academic performance (Melhuis, 2010). Furthermore, previous research has indicated the importance of home learning environment for academic skills (Andrers et al., 2013; Lehrl et al., 2016; Torppa et al., 2007). In the present study, maternal activities at home were used as an indicator of the home learning environment (Silinskas et al., 2010, 2012).

Pre-reading skills. Children's pre-reading skills at the beginning of kindergarten were measured with two tests: initial phoneme identification and letter knowledge (ARMI; a tool for assessing reading and writing skills in Grade 1; Lerkkanen, Poikkeus, & Ketonen, 2006). Initial phoneme identification was assessed using a 10-item test. For each item, the child was presented with four pictures of objects along with their names and was asked to select the correct picture based on the oral presentation of an initial phoneme related to a target. The

total score corresponded to the number of correct items (maximum value of 10; Kuder-Richardson reliability = .74). Letter knowledge was assessed using a naming test of all 29 letters in the Finnish language. The letters were presented as uppercase letters in three rows and were shown to the child one row at a time. The total score corresponded to the number of correctly named items (maximum value of 29; Kuder-Richardson reliability = .95). The scores for initial phoneme identification and letter knowledge were standardized, and a variable measuring pre-reading skills was calculated as the mean of these two scores (α = .95).

Pre-math skills. Children's pre-math skills at the beginning of the kindergarten year were measured with number sequences test. The number sequences test consisted of four subtasks: (a) counting forward, stopped when the child reached 31; (b) counting backward from 12, stopped after five correctly counted numbers; (c) counting backward from 23, stopped after five correctly counted numbers; and (d) counting forward from 6 to 13. The more difficult third subtask was given only if the child mastered the easier second task. The total score was based on the number of correct items (2 points for each task if performed without errors, 1 point if the performance contained one to two errors) with a maximum score of 8 points (α = .69).

Nonverbal reasoning. Nonverbal reasoning ability was assessed using the Spatial Relations subtest from the Woodcock and Johnson (1977) test battery. The test requires the child to identify the subset of pieces needed to form a complete shape (i.e., "Two of these pieces (a, b, c, d) go together to make this (e). Tell me which two pieces."). The test is a measure of spatial visualization that involves complex, multistep manipulation of spatial information (i.e., comprehending spatial forms or shapes, mentally rotating or manipulating them, and matching). A maximum of 31 tasks can be attempted within the 3-min time limit (maximum score = 31; Kuder–Richardson reliability = .72).

Maternal education. Mothers were asked about their level of vocational education using a questionnaire item with a 7-point scale (1 = *no further qualification after comprehensive school*; 7 = *licentiate or doctoral degree*). The scale was revised from 7 points to 5 points as follows: 1 = *no occupational education or only short courses*, 2 = *vocational school degree*, 3 = *vocational college degree*, 4 = *polytechnic degree or Bachelor's degree*, 5 = *university degree or licentiate/doctoral degree*. A total of 6.8% of mothers had no vocational education, 31.3% had a vocational school degree, 23.2% had a vocational college degree, 12.1% had a polytechnic degree or a Bachelor's degree, and 26.5% had a university degree.

Maternal academic activities at home. To measure the frequency of maternal reading- and math-related activities with their children at home, we employed questions based on the ones used previously by Silinskas et al. (2010, 2012). First, the mothers were asked to rate the frequency of teaching of reading/math at home by the following questions: "How often do you teach/have previously taught letters to your child?", "How often do you teach/have previously taught numbers to your child?", "How often do you teach/have previously taught your child to read?", and "How often do you teach/have previously taught your child oral or written calculation tasks?" on a 5-point scale (1 = *not at all/very rarely* to 5 = *very often/daily*). Cronbach's alpha for the sum score of reading-related activities was .74 and for math-related activities .68. Finally, the mothers were asked to rate the frequency of shared reading with a single question: "How often do you read to your child/read books together with your child?" on a 5-point scale (1 = *less than once a week*, 2 = *1–3 times a week*, 3 = *4–6 times a week*, 4 = *once a day*, and 5 = *more than once a day*).

Procedure and Measures in Elementary School

Measures in Grades 1–4. In elementary school, children's reading and arithmetic fluency was tested four times (at the end of Grades 1, 2, 3, and 4). In addition, the children's

reading comprehension, arithmetic reasoning, and multiplication were assessed at the end of Grade 4. All tests were administered by trained testers in group test situations during regular school hours. Furthermore, teachers were asked to fill in questionnaires regarding the structural quality of their class at each Grade.

   Reading fluency. A group-administered subtest of the nationally normed reading test battery (ALLU; Lindeman, 1998) was used to assess *word-level reading*. On the test, a maximum of 80 items can be attempted within a 2-min time limit. On each item, the child was asked to read silently four phonologically similar words and draw a line connecting a picture to the word semantically matching the picture. Due to the nature of this speed test, the score reflects the child's fluency in reading the stimulus words and his or her accuracy in making the correct choice from among the alternatives. In the highly transparent Finnish language, differences between children have been typically identified on this type of reading speed test. The Kuder–Richardson reliability coefficient for the reading fluency task was .97, .97, .97, and .87, in Grades 1–4, respectively.

   Arithmetic fluency. Arithmetic fluency was assessed using the Basic Arithmetic Test (Aunola & Räsänen, 2007). On the test, a maximum of 28 items, consisting of 14 items for addition (e.g., 2 + 1 =; 3 + 4 + 6 =) and 14 items for subtraction (e.g., 4 – 1 =; 20 – 2 – 4 =), are attempted within a 3-minute time limit. The items are identical in Grades 1 to 3, but in Grade 4, more advanced items were added to the task. In Grade 4, the test consisted of 28 items containing 12 addition, 13 subtraction, 1 multiplication (12 × 28 =), and 2 division problems (e.g., 240 / 80 =). Task difficulty increases gradually across the test. The test indexes a combination of speed and accuracy of math performance, and the test's psychometrics have been shown in a number of earlier publications (e.g., Zhang et al., 2014). The test score was derived by calculating the total number of correct answers (maximum

score 28; Kuder-Richardson reliability = .85, .89, .87, and .85, in Grades 1, 2, 3 and 4, respectively).

Measures in Grade 4. Various reading and math measures were used in Grade 4.

Reading comprehension. Two group-administered tests were used to assess reading comprehension: text-level and sentence-level comprehension. On the nationally normed reading comprehension of text (ALLU; Lindeman, 1998), the children were asked to silently read a factual story and answer 12 multiple choice questions. The children received 1 point for each correct answer (maximum score of 12). They completed the task at their own pace, but the maximum time allotted was 45 min. The test battery is directed at children in Grades 1 to 6, and the story and the questions are different at each grade level. In Grade 4, the topic of the text concerned "the need for light of plants." The Kuder-Richardson reliability was .76. Reading Comprehension (Sentences) (TOSREC; Wagner, Torgesen, Rashotte, & Pearson, 2009; Finnish version by Lerkkanen & Poikkeus, 2009) was used to assess silent reading efficiency. The children were asked to read sentences silently and to verify whether the sentences were true or false by circling *yes* or *no*. The sentences were true or false statements that were based on fundamental knowledge that was expected to be well-known to young children. The maximum time allotted was 3 min for the 60 sentences. The number of correct responses (maximum 60 points) was used to measure achievement in this reading comprehension task (Kuder–Richardson reliability = .94).

Arithmetic reasoning. Arithmetic reasoning was assessed using the arithmetic reasoning test (NMART, Koponen & Räsänen, 2003; see also Langdon & Warrington, 1997). Arithmetic reasoning was measured with a set of tasks in which students were shown a sequence of three numbers (e.g., 3, 5, 7) and asked to select from among four alternative numbers the number that best continued the sequence. First, the tester went over four example tasks together with the students, after which the students were given a set of similar tasks to

complete within a time limit of 10 min. One point was given for each correct answer. The

final score was the total number of correct answers (maximum score possible = 30). The

Kuder–Richardson reliability coefficient was .91.

Multiplication. Children's multiplication skills were measured with a multiplication

test (Koponen & Mononen, 2010) in which a total of 120 items containing multiplication

items (e.g., $8 \times 9 =$; $5 \times 3 =$) can be attempted within a 2-min time limit. The final score was

the total number of correct answers (maximum score possible = 120). The Kuder–Richardson

reliability coefficient was .86.

Structural quality in Grade 1. In Grade 1, teachers were asked to rate their teaching

experience, class size, a number of teaching assistants, a number of IEP students, and a

number of students with immigrant status in their classroom. Teachers reported their teaching

experience on a six-point scale (0 = *not at all*, 1 = *less than a year*, 2 = *1—5 years*, 3 = *6—10*

years, 4 = *11—15 years*, 5 = *more than 15 years*). The number of teaching assistants and

length of teaching experience were used as indicators of high structural quality whereas class

size, the number of IEP students and the number of students with immigrant status were used

as indicators of low structural quality. As the final step, structural quality variables were

included as control variables to the final models to check whether the main results remained

the same when controlling for structural quality in Grade 1.

Analysis Strategy

The research questions were examined using latent growth curve modeling (RQ1) and

structural equation modeling (SEM) (RQ2). Latent growth models (LGMs) were first

estimated separately for reading skills and math skills. These two models (RQ1) included an

intercept (representing the initial level of Grade 1) and a slope (representing the rate of

change across Grades 1–4). With regard to the intercept factor, factor loadings of the observed

variables were fixed as 1 for each measurement point. To model linear growth, the values for

the slopes were fixed at 0, 1, 2, and 3. However, because linear growth models did not fit the data, for the growth factor, the first two factor loadings were fixed to correspond to a time scale (i.e., 0, 1), but the last two factor loadings were freely estimated by the program. These findings are similar to those of previous research on early arithmetic development among Finnish children (Aunola et al., 2004; Zhang et al., 2014). Thus, we consider it theoretically appropriate to free the factor loadings for slope (see also Aunola et al., 2004; Zhang et al., 2014). By doing so, the level can be interpreted as the initial level at first grade, and the slope can be interpreted as the amount of change from the first grade to the fourth grade. Freely estimated parameters can be interpreted so that the growth is linear between Grades 1 and 2; after this period, the mean growth of academic skills is slower.

Second, we combined the two models into a parallel processes latent growth model and entered teacher–child interactions and covariates (pre-academic skills, nonverbal reasoning, child's gender, shared reading, maternal teaching of academic skills, and maternal level of education). The intercepts were allowed to correlate to examine the extent to which the levels of reading and math skills were associated in the first grade. The slopes were also allowed to correlate to inspect whether the rate of change in reading skills was related to the rate of change in math skills. We also examined whether the intercepts of reading skills and of math skills predicted the rate of change in the other construct.

As the next step, a SEM model (RQ2) was specified, in which a composite score of standardized reading and math skills at the end of Grade 4 was regressed on teacher–child interactions, while controlling for other confounding factors. In addition, academic skills (standardized scores of arithmetic and reading fluency) in Grade were controlled for. Because we were interested in examining whether being in a specific kindergarten classroom was associated with academic skills in elementary school, we used kindergarten classroom membership as a clustering variable in all the analyses (49 clusters with an average cluster

size of 10.51). Structural quality variables in first grade of elementary school were used as control variables in the final models to investigate whether the results would change after including these factors.

The analyses were performed using the Mplus statistical package (version 7.3; Muthén & Muthén, 1998–2013). The standard missing-at-random (MAR) approach was applied (Muthén & Muthén, 1998–2013). The parameters of the models were estimated using full-information maximum likelihood estimation (FIML) with non-normality robust standard errors (MLR estimator; Muthén & Muthén, 1998–2013). FIML has been recommended as one of the most appropriate methods for dealing with possible selective attrition (e.g., Enders, 2010). In addition, simulation studies have shown that FIML provides less biased regression parameter estimates than other missing data procedures (e.g., Enders, 2001). The amount of missing values ranged from 0% to 19.81% (see Table 1). All models were estimated using the "Type = Complex" approach. This method estimates the models at the level of the whole sample, correcting distortions of standard errors and chi-square values in the estimation caused by clustering of the observations (i.e., classroom differences). The goodness-of-fit of the estimated models was evaluated using four indicators: the chi-square coefficient, comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). According to Kline (2011), CFI and TLI values above .95, RMSEA values below .06, and SRMR values close to .08 can be considered as indicators of good fit of the model to the data.

Results

The descriptive statistical values of the study variables are shown in Table 1, and correlations between the study variables are shown in Table 2.

Level of and Growth of Reading and of Math Skills

First, we specified latent growth curve models separately for reading and math skills. The fit of the unconditional model to reading skills was good: χ^2 (3, $n = 473$) = 5.637, $p > .05$; CFI = .996; TLI = .993; RMSEA = .043; SRMR = .045. The parameter estimate was 19.202 (*S.E.* = 0.534, $p < .001$) for the initial level (intercept) and 5.942 (*S.E.* = 0.411, $p < .001$) for growth (slope). There was significant individual variability in the intercepts and in the slopes of reading skills (intercept = 52.682, *S.E.* = 4.224, $p < .001$; slope = 1.844, *S.E.* = 0.421, $p < .001$), which suggests that the Grade 1 levels of reading skills and the rate of change over time differed between children. Children with lower initial reading skills were slightly more likely to show greater progress, as indicated by the correlation coefficient (*r*) of –.27 between the slope and intercept ($p < .01$).

Next, we specified a model for math skills. The fit of the unconditional latent growth curve model for math skills was good: χ^2 (2, $n = 476$) = 5.940, $p = .051$; CFI = .992; TLI = .977; RMSEA = .064; SRMR = .045. The parameter estimate was 10.562 (*S.E.* = 0.246, $p < .001$) for the initial level (intercept) and 5.460 (*S.E.* = 0.219, $p < .001$) for positive slope (growth). There was significant individual variability in the intercepts and in the slopes for math skills (intercept = 15.766, *S.E.* = 1.584, $p < .001$; slope = 2.194, *S.E.* = 0.388, $p < .001$), which suggests that Grade 1 math skills levels and the rate of change over time differed between children. Children with lower initial math skills were slightly more likely to show greater progress, as depicted by the correlation coefficient (*r*) of –.59 between the slope and intercept ($p < .001$). Based on the modification indices, a residual correlation was assumed to exist between math skills at Grade 2 and at Grade 3.

We then combined the separate LGMs into a parallel processes latent growth model and entered teacher–child interactions and the covariates into the model. The model was trimmed to contain only the statistically significant paths (Figure 1). The model with predictors fit the data well (χ^2 [90, $n = 515$] = 112.071, $p = .058$; CFI = .989; TLI = .988;

RMSEA = .022; SRMR = .054). In the final model, the estimated means of the intercepts and slopes of the final LGM resembled the estimates of the separate models reported above.

The results (Figure 1) indicated that the intercepts of reading skills and math skills were positively associated. The higher the reading skills the children had in the first grade, the higher their concurrent math skills were. The slopes also correlated indicating that the change in reading skills was associated with the change in math skills. The intercept of reading skills negatively predicted the slope in math skills: the higher the reading skills the children had the slower growth of math skills they showed across Grades 1–4. The results further showed that high-quality teacher–child interactions in kindergarten were associated with a high initial level of reading skills ($\beta = .10$, $p < .05$) but not with the slope of reading skills. Children with higher skills in nonverbal reasoning and higher pre-reading and pre-math skills had a higher initial level of reading skills in Grade 1. Maternal teaching of math was negatively related to a higher initial level of reading skills. Higher pre-reading skills were a predictor of slower growth of reading skills. Maternal shared reading in kindergarten positively predicted faster growth of reading skills.

In addition, the results showed that high-quality teacher–child interactions in kindergarten were associated with a high initial level of ($\beta = .06$, $p < .05$) but not with the slope of math skills. Children with high pre-math skills, pre-reading skills and nonverbal reasoning skills in kindergarten showed a high initial level of math skills in elementary school. Children's high pre-reading skills in kindergarten negatively predicted the slope of math skills: the higher the pre-reading skills the children had the slower growth of math skills they showed across Grades 1–4. As the last step of the analyses, structural quality variables were included into the final model. The results remained the same when controlling for structural quality in Grade 1.

Longitudinal Associations between Teacher–Child Interactions and Academic Skills

A SEM model was specified to investigate the longitudinal associations between kindergarten teacher–child interactions and academic skills in Grade 4.

The trimmed model fit the data well (χ^2 [61] = 79.229, p = .058; CFI = .943; TLI = .948; RMSEA = .025; SRMR = .055). The results (Figure 2) showed that teacher–child interactions in kindergarten were positively associated with Grade 4 academic skills (β = .06, p <.05) when several confounding factors measured in kindergarten and academic skills in Grade 1 were controlled for. The results also showed that maternal level of education, nonverbal reasoning, pre-reading skills, and maternal teaching of math measured in kindergarten were positively related to children's academic skills 4 years later. Academic skills in Grade 1 were positively linked to academic skills in Grade 4 indicating stability of academic performance. In addition, maternal teaching of reading was negatively associated with academic skills in Grade 4. As the last step of the analyses, structural quality variables were included into the final model. The results remained the same when controlling also for the structural quality in Grade 1.

Discussion

The present study contributes to the existing literature (e.g., Belsky et al., 2007; Burchinal et al., 2008; Hamre et al., 2014; Vandell et al., 2010) by examining the extent to which quality of teacher–child interactions in kindergarten contributes to children's academic skills across elementary school years. The results showed that strong emotional, organization, and instructional supports in kindergarten were positively related to the initial level of children's reading and math skills. In addition, high-quality teacher–child interactions in kindergarten were positively associated with subsequent, more advanced academic skills four years later in elementary school. Overall, the results suggest that high-quality teacher–child interactions in kindergartens, even without formal teaching of reading and mathematics, provide children with a beneficial start to schooling. These results are of particular importance

because they complement the intensive focus of previous research on how early teacher–child interactions impact on children's development. It should be noted that our findings emerged after taking into account several important factors, such as children's pre-academic skills, maternal activities at home, and structural quality in elementary school. The results are also important because this study is among very few such studies that have investigated longitudinal associations between quality of teacher–child interactions and academic skills in Europe.

Associations with the Initial Level and Growth of Academic Skills

We investigated the extent to which teacher–child interactions in kindergarten are associated with the initial level of and growth of reading and math skills. Partly in line with our hypothesis (H1a) and previous studies (e.g., Burchinal et al., 2010; Curby et al., 2009), the results showed that the high-quality teacher–child interactions in kindergarten were associated with the initial level of reading and math skills. These results suggest that warm and sensitive teacher–child interactions, well-organized activities with proactive behavior management, and process-oriented feedback provide children with a good start to schooling. Previous studies by Burchinal et al. (2010) and Curby et al. (2009) have also shown that emotionally supportive teacher–child interactions are important for early literacy skills. In addition, some scholars (Cadima et al., 2010; Ponitz et al., 2009) have provided evidence of the importance of high-quality classroom organization for literacy gains. There are also studies showing that instructional support promotes the development of pre-academic skills (Burchinal et al., 2010; Mashburn et al., 2008). In line with our hypothesis (H1a) and a previous study by Anders and colleagues (2013), we also found a positive association between the teacher–child interactions in kindergarten and the initial level of math skills. The present study is among few such studies (e.g., Pianta, Belsky et al., 2008) that provide evidence of the importance of all domains of teacher–child interactions for future math skills,

as previous studies have mostly indicated the importance of instructional support and

classroom organization for math skills (Mashburn et al., 2008). In a similar vein, Peisner-

Feinberg at al. (2001) demonstrated that quality of preschool practices predicted children's

math skills four years later, in second grade.

Previous studies by Hamre et al. (2014), Mashburn et al. (2008), and Burchinal et al.

(2008, 2010) showed that instructional quality rather than emotional quality is associated with

children's academic outcomes (see also Keys et al., 2013 for a meta-analysis). Moreover, in a

recent meta-analysis that presented results across five early child-care studies (Burchinal et

al., 2011), the association between early childhood care quality and academic outcomes,

although curvilinear, was only observed in children who experienced higher quality care and

who received mostly instructional (rather than emotional) support. Our results, in turn,

showed that a composite score of teacher–child interactions was associated with the initial

level of math and reading skills in the first grade of elementary school. This finding of

predictive effect provides evidence that the quality of children's experiences in terms of

emotional, organizational, and instructional supports before formal schooling is an important

predictor of their readiness for school.

Our data did not provide evidence of a significant association between the quality of

teacher–child interactions and the growth of math and reading skills (our hypothesis H1b),

although previous studies by Anders et al. (2012), Lehrl et al. (2016), and Curby et al. (2009)

showed that the process quality of classrooms was related to the growth of academic skills.

Pianta, Belsky et al. (2008) indicated that emotional aspects of teacher–child interactions were

positively related to growth in math and reading fluency from 54 months to Grade 5. One

explanation for our insignificant results is that reading and arithmetic fluency are skills that

are automatized very rapidly after formal instruction begins, and therefore the quality of

teacher–child interactions is not related anymore to the growth of these types of automatized

skills in the early years of elementary school. Another explanation is that we investigated linear associations between teacher–child interactions and academic skills, whereas recent studies provided evidence of certain thresholds for quality, which means that only quality scores in the moderate to high range are influential (Burchinal et al., 2010, 2011; Weiland et al., 2013). Future studies should perhaps examine the curvilinear associations between academic skills and teacher–child interactions and the thresholds of interactional quality. A related finding of the present study was that higher pre-reading and pre-math skills predicted slower growth of reading and math skills, which seems to indicate that there is less to gain in later years in children with high pre-academic skills.

Associations with Academic Skills at the End of Grade 4

We also examined whether teacher–child interactions in kindergarten are associated with reading and math skills four years later in elementary school. Partly in line with Hypothesis 2 (Peisner-Feinberg et al., 2001), the results showed that the quality of teacher–child interactions measured in kindergarten classrooms was positively associated with academic skills at the end of Grade 4: The higher the quality of emotional, organizational, and instructional support in kindergarten, the better the child's academic skills four years later in elementary school. Similarly, Hamre et al. (2014) showed recently that children made the most gains in early literacy skills during their preschool year when they have responsive preschool teachers, that is, teachers who provide high-quality emotional, organizational, and instructional support. Our results suggest that high-quality kindergarten teacher–child interactions provide children with a better start to school and a long-lasting advantage for progress in reading and math skills as they move through elementary school. It should be noted that the academic skills in the first grade of elementary school were controlled for in the analyses. The results are also in line with previous studies (Belsky et al., 2007; Peisner-Feinberg et al., 2001; Sylva et al., 2004, 2008; Vandell et al., 2010) which suggest that early

education before formal schooling has a beneficial effect on children's academic achievements later on in elementary school.

There are some potential mechanisms that are likely to explain the findings of our study. First, our findings in terms of emotional support are in line with the theoretical assumptions that the key influences on children's learning involve proximal processes that children directly experience in their everyday contexts (Bronfenbrenner & Morris, 2006; Pianta, 1999) of which teacher–child interactions in early education classrooms are important. Based on the propositions of the self-determination theory (Ryan & Deci, 2000) and attachment theory (Bergin & Bergin, 2009), warmth and responsiveness in relationships between children and adults in these contexts critically foster children's autonomy, engagement, and experiences of connectedness. It can be assumed that students who see teachers as warm and supportive are more likely to pursue goals valued by teachers, such as engagement in academic activities. Although this study did not include variables related to children's motivation and their achievement behaviors, the attitudes toward learning and work habits that children already have in kindergarten are known to persist into elementary school (Hirvonen, Tolvanen, Aunola, & Nurmi, 2012).

Second, efficient organization of the structure and management of activities in kindergarten have been suggested to promote behavioral engagement which are crucial factors that facilitate successful learning outcomes (Cadima et al., 2015). By setting clear rules and expectations for behavior, kindergarten teachers help children in developing important skills for further schooling, such as self-regulation and emotional regulation skills (Rimm-Kaufman et al., 2009). Teachers who show high-quality classroom organization skills also ensure that children spend more time on the tasks assigned and are engaged in academic activities, thus ensuring that the maximum time is spent in learning (Pianta, La Paro et al., 2008).

Third, children's thinking and learning in the context of kindergarten classrooms are promoted by high-quality instructional support in the form of process-oriented, constructive feedback and scaffolding at an optimal level for the child's current skills (Hamre et al., 2014; Pianta, La Paro et al., 2008). High-quality instructional support in kindergarten promotes children's higher-order thinking skills, facilitates their language skills and provides children with models of metacognitive processing, the skills which enhance success in academic achievement.

Limitations and Future Directions

The present study has several limitations. First, as the study was correlational, causal inferences cannot be drawn. Second, the CLASS instrument focuses on classroom interactions at a general level without paying attention to the content of the activities. Future studies would benefit also from content-specific observational methods, such as analysis of individualized student instruction in literacy and math learning (ISI; Connor et al., 2009). Third, the internal consistency of maternal teaching of reading and mathematics was rather low. Fourth, although we controlled for structural quality in elementary school, we were not able to rule out the possibility that elementary school teachers may shape the students' learning environment by their instructional approaches when teaching reading and mathematics. Lehrl et al. (2016), for example, showed that the longitudinal effects of early education on academic skills partly depend on the classroom experiences in the first years of school (see also Anders et al., 2012). Future studies would benefit from investigating the joint effects of the interactional quality of kindergarten and elementary school.

Fifth, the effect sizes for the quality of teacher–child interactions during kindergarten in the present study were small (standardized betas .06-.07). Our results indicated that teacher–child interactions in kindergarten classrooms were related to subsequent academic skills, but previous academic skills and nonverbal reasoning were found to be even better

predictors. The small effect may be explained by the highly homogenous training required of all kindergarten teachers in Finland, which leads to only small differences in teaching practices. However, it should be noted that the effect sizes in the present study were similar to those found in previous studies (e.g., Burchinal et al., 2010; Hamre et al., 2014; Mashburn et al., 2008).

Finally, the Finnish educational system differs from that of many other countries, which should be noted when trying to generalize the findings. For example, play-centered familiarization with literacy and support for phonological awareness are emphasized in Finnish kindergartens rather than formal instruction of reading and math.

Conclusions

As more children enter early childhood education programs, there is an evident need to identify processes in the preschool and kindergarten classrooms that support children's development and prepare them for the requirements of elementary school. The results of the present study broaden our previous understanding of the longitudinal associations between kindergarten teacher–child interactions and children's subsequent academic skills in elementary school. Our results indicated that high-quality teacher–child interactions in terms of emotional and instructional supports and classroom organization in kindergarten are related to the initial level of reading and math skills at school entry. In addition, a composite score of emotional, organizational and instructional support was positively associated with academic skills later in Grade 4 in elementary school. These results suggest that high-quality teacher–child interactions in kindergarten provide children with a good start for schooling in a kindergarten context that does not focus on the instruction of academic skills, and that these early benefits are, at least to some extent, maintained in later years. Overall, in addition to cognitive stimulation, our results call attention to the importance of feeling emotionally comfortable and supported in the classroom.

The study also provides practical implications with regard to initial teacher training and in-service training. For example, the findings emphasize the meaningful role of warm, supportive, and sensitive teacher–child interactions in kindergarten for further academic development in elementary school. Although a host of US studies has shown the importance of instructional support for good academic outcomes, our results suggest that also emotional and organizational supports in the early education context are particularly important for children's reading and math skills in elementary school. When children have early education teachers who they can trust, who provide the support they need, and who help them regulate their behavior, they are better able to invest their attention and energy in learning. Our results demonstrate the importance of investment in the quality of teacher–child interactions in kindergarten by setting clear rules and expectations; giving process-oriented feedback; and fostering warm, predictable, and respectful interactions. These types of teacher–child interactions provide children with experiences that foster their engagement in learning and motivation to learn, and affect the children's long-term aspirations and attitudes toward school, which is reflected in their scholastic outcomes.

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Table 1

Descriptive Statistics of the Study Variables

Variable	*n*	Missing %	*M*	*SD*	Range Potential	Range Actual	Skewness
Kindergarten Measures							
Phonological Awareness (Kf)	507	1.55	7.43	2.39	0–10	0–10	-.77
Letter Knowledge (Kf)	507	1.55	16.63	8.81	0–29	0–29	-.20
Pre-reading Skills (Kf)	507	1.55	-.008	.86		-2.47–1.22	-.32
Pre-5.12math Skills (Kf)	507	1.55	4.33	2.85	0–8	0–8	-.18
Nonverbal reasoning (Ks)	503	2.33	14.13	2.25	0–31	5–21	-.21
Maternal Shared Reading (Ks)	413	19.81	2.86	1.19	1–5	1–5	-.10
Maternal Teaching of Reading (Ks)	415	19.44	2.66	.88	1–5	1–5	.35
Maternal Teaching of Mathematics (Ks)	415	19.44	2.60	.84	1–5	1–5	.12
Sex (0 = girl; 1 = boy)	515	0	.47	.49	0–1	0–1	.11
Maternal Education [a]	413	19.81	3.12	1.03	1–5	1–5	.20
Context (0 = elementary school; 1 = day care)	511	0.8	.72	.45	0–1	0–1	-.96
Age range (0 = 6-year-olds; 1 =wider age range)	511	0.8	.52	.50	0–1	0–1	-.09
Academic Skills Grades 1–4							
Reading Fluency (G1)	473	8.16	19.20	9.26	0–80	0–50	.68
Arithmetic Fluency (G1)	473	8.16	10.57	4.11	0–28	0–26	.50
Reading Fluency (G2)	457	11.26	25.20	7.59	0–80	3–50	.27
Arithmetic Fluency (G2)	455	11.65	16.05	4.74	0–28	0–27	-.08
Reading Fluency (G3)	454	11.84	36.57	8.54	0–80	1–62	-.21
Arithmetic Fluency (G3)	454	11.84	19.39	4.42	0–28	0–27	-.52
Reading Fluency (G4)	420	18.45	36.88	9.13	0–80	4–65	.16
Reading Comprehension (G4)	443	13.98	8.17	1.46	0–12	0–12	-.49
Reading Sentences (G4)	447	13.20	45.93	9.02	0–60	2–60	-.59
Arithmetic Fluency (G4)	443	13.98	17.05	4.04	0–28	0–26	-.63

Variable	N		M	SD			
Arithmetic Reasoning (G4)	447	13.20	17.53	4.06	0–30	0–28	-.36
Multiplication (G4)	447	13.20	24.30	11.15	0–120	0–77	1.42
Teacher–Child Interactions in Kindergarten							
Positive Climate (Ks)	515	0	5.28	.86	1–7	2.75–6.50	-1.38
Teacher Sensitivity (Ks)	515	0	5.28	.76	1–7	3.00–6.35	-1.24
Regard for Student Perspectives (Ks)	515	0	4.65	.87	1–7	2.60–6.00	-.63
Behavior Management (Ks)	515	0	5.41	.88	1–7	2.70–6.65	-1.21
Productivity (Ks)	515	0	5.66	.46	1–7	4.06–6.42	-1.63
Instructional Learning Formats (Ks)	515	0	4.86	.72	1–7	2.47–5.95	-1.65
Concept Development (Ks)	515	0	3.82	.89	1–7	1.70–5.30	-.42
Quality of Feedback (Ks)	515	0	3.88	1.07	1–7	1.60–5.62	-.40
Language Modeling (Ks)	515	0	4.21	.91	1–7	1.65–5.75	-.80
Emotional Support (Ks)	515	0	5.12	.78	1–7	2.9–6.23	-1.15
Classroom Organization (Ks)	515	0	5.34	.64	1–7	3.19–6.27	-1.56
Instructional Support (Ks)	515	0	3.96	.91	1–7	1.64–5.54	-.61
Structural Quality Grade 1							
Teaching Experience (G1) [b]	430	16.50	4.08	.85	0–5	0–5	-.81
Class Size (G1)	477	7.38	20.12	5.55		4–30	-1.09
A Number of Assistants (G1)	433	15.92	.59	.43		0–3	.82
A Number of IEP Students (G1)	433	15.92	.65	1.28		0–9.67	4.21
A Number of Immigrant Students (G1)	433	15.92	.28	.84		0–5	4.40

Note. (Kf) = kindergarten fall, (Ks) = kindergarten spring, (G1) = Grade 1 spring, (G2) = Grade 2 spring, (G3) = Grade 3 spring, (G4) = Grade 4 spring. [a]

Mothers' vocational education was assessed on a 5-point scale: no vocational education or only short vocational courses; a vocational school qualification; a

college qualification; a bachelor's degree from university; a master's degree and a licentiate or doctoral degree. [b] teachers' work experience was assessed on a

6-point scale: 0 = none, 1 = less than a year, 2 = 1–5 years, 3 = 6–10 years, 4 = 11–15 years, 5 = more than 15 years.

Table 2

Correlations among the Study Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Pre-reading skills (Kf)	1.00																			
2	Pre-math skills (Kf)	.56***	1.00																		
3	Nonverbal reasoning (Ks)	.22***	.33***	1.00																	
4	Maternal education	.19***	.12*	.09	1.00																
5	Maternal teaching of reading (Ks)	21**	.13*	.07	-.05	1.00															
6	Maternal shared reading (Ks)	.18***	-.01	-.08	.17***	.13**	1.00														
7	Maternal teaching of math (Ks)	-.01	.04	.04	-.10*	.63***	.15**	1.00													
8	Emotional Support (K)	-.01	-.06	.04	-.04	.02	-.02	.00	1.00												
9	Classroom Organization (K)	-.08	-.12*	.01	-.09	.02	-.06	.03	.87***	1.00											
10	Instructional Support (K)	-.03	-.12+	-.01	-.06	.06	-.02	.02	.83***	.79***	1.00										
11	Reading Fluency (G1)	.47***	.38***	.28***	.03	.13**	-.01	-.04	.07	.06	.03	1.00									
12	Arithmetic Fluency (G1)	.35***	.48***	.30***	.08+	.07	-.02	.01	.08	-.02	.04	.44***	1.00								
13	Reading Fluency (G2)	.45***	.36***	.28***	.07	.11*	.04	-.04	.11**	.08+	.06	.73***	.42***	1.00							
14	Arithmetic Fluency (G2)	.37***	.45***	.28***	.14**	.13**	.03	.09+	.07	.04	.04	.41***	.65***	.45***	1.00						
15	Reading Fluency (G3)	.33***	.33***	.27***	.06	.10+	.06	-.02	.07+	.04	.01	.62***	.38***	.70***	.44***	1.00					
16	Arithmetic Fluency (G3)	.34***	.48***	.36***	.16**	.08+	-.02	.08	.06*	.02	-.02	.41***	.61***	.45***	.75***	.45***	1.00				
17	Reading Fluency (G4)	.35***	.35***	.22***	.13***	.08+	.10+	.02	.11*	.06	.03	.59***	.40***	.68***	.44***	.71***	.49***	1.00			
18	Arithmetic Fluency (G4)	.21***	.37***	.24***	.09+	-.00	-.04	.06	.03	.01	.01	.30***	.47***	.32***	.58***	.33***	.63***	.40***	1.00		

19	Reading Skills (G4)	.48***	.39***	.30***	.13*	.11*	.10+	.01	.10*	.08+	.08+	.66***	.44***	.76***	.53***	.79***	.59***	.45***	.47***	1.00	
20	Math Skills (G4)	.39***	.51***	.36***	.18***	.00	-.04	.05	.09*	.04	.04	.46***	.71***	.47***	.78***	.47***	.85***	.53***	.78***	.64***	1.00

Note. (Kf) = Kindergarten fall, (Ks) = Kindergarten spring, (G1) = Grade 1 spring, (G2) = Grade 2 spring, (G3) = Grade 3 spring, (G4) = Grade 4 spring. $+ p < .09$; $* p < .05$; $** p < .01$; $*** p < .001$.

Figure Captions

Figure 1. The associations between the teacher–child interactions in kindergarten and the

initial level of and growth of reading and math skills across Grades 1–4.

Note. Standardized estimates. *p < .05; **p < .01; ***p < .001*.

Figure 2. The longitudinal associations between teacher–child interactions in kindergarten

and academic skills in Grade 4.

Note. Standardized estimates. *p < .05; **p < .01; ***p < .001*.