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**Linguistic environment of preschool classrooms: What dimensions support children’s language growth?**

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**Highlights**

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This study explored dimensionality of preschool classroom’s linguistic environment.

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Our data supported a tri-dimensional structure.

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The communication-facilitating dimension predicted growth in children’s vocabulary.

**Abstract**

Individual differences in young children’s language acquisition reflect in part the variability in the language-learning environment that they experience, both at home and in the classroom. Studies have examined various dimensions of the preschool classroom language environment, including linguistic responsivity of early childhood educators, data-providing features of teachers’ talk, and characteristics of the systems-level general environment, but no study has examined the unique contribution of each dimension to children’s language growth over time. The goals of this study were to determine how best to represent the dimensionality of the preschool classroom’s linguistic environment and to determine which dimensions are most strongly associated with children’s language development. Participants were teachers in 49 preschool classrooms and a random sample of children from each classroom (330 children between 40 and 60 months of age, *M* = 52 months, *SD* = 5.5). Children’s grammar and vocabulary skills were measured at three time-points, and the classroom linguistic environment was assessed with measures representing teachers’ linguistic responsivity, data-providing features of teachers’ talk, and systems-level general quality. Using exploratory structural equation modeling (ESEM), we determined that the classroom language environment is best characterized by a three-dimensional model. A multilevel latent growth model subsequently showed that only one of the three dimensions, teachers’ communication-facilitating behaviors, predicted growth in children’s vocabulary from preschool to kindergarten. Implications for teacher professional development are discussed.

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**Keywords**

Preschool

Oral language

Classroom quality

Vocabulary growth

**1. Introduction**

There are many universalities in young children’s language acquisition, such as when children tend to speak their first word as well as when they start to use grammatical morphemes, yet there are also considerable individual differences, even within a relatively constrained cultural or linguistic context ([Rowe, Raudenbush, & Goldin-Meadow, 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0250)). These individual differences reflect both the influence of nature on children’s language development (i.e., one’s genetics or biology) as well as the influence of nurture, representing the child’s environment ([Hayiou-Thomas, Dale, & Plomin, 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0130)). Interestingly, longitudinal twin studies show that from birth to about age five, the dominant influence on language growth is the child’s environment, accounting for about 60–70% of the variance in language skills, as compared to about 25% for genetic factors (the unaccounted-for remainder reflects non-shared environmental factors and error) ([Spinath, Price, Dale, & Plomin, 2004](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0275)). Over time, the dominant role of the environment for influencing children’s language skills tends to diminish, with the contribution of genetics becoming increasingly prominent into adolescence (see [Hayiou-Thomas et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0130)). Some speculate that this shift reflects the decreasing variability of children’s environments as they become older and progress through the curricula of formal schooling ([Hayiou-Thomas et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0130)). That is, prior to formal schooling, there is considerable variability in the language-learning environment that children experience, and this variability appears to have significant implications for children’s early linguistic trajectories.

**1.1. Children’s learning–learning experiences in early-education settings**

Over the last several decades, numerous studies have sought to document variability in young children’s language-learning environments, including studies of both the home and preschool settings ([Dickinson & Smith, 1994; Girolametto & Weitzman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0045); [Justice, McGinty, Zucker, Cabell, & Piasta, 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0155); [Landry, Smith, & Swank, 2006](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0175); [Yoder & Warren, 1999](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0305)). This work has examined various dimensions of children’s language-learning environments, often for the purpose of understanding the relations between a specific dimension of the environment and children’s language development. Dimensions often investigated within the early-education setting include (1) linguistic responsivity of early childhood educators, (2) data-providing features of teachers’ talk, and (3) systems-level general environment; each will be reviewed in turn. Although research to date suggests that each dimension is associated with children’s language growth, a key limitation of this literature is that no study has examined the distinctiveness of these dimensions nor the unique contribution of each dimension to children’s language growth over time. The primary goal of the present study is to address these limitations by identifying what specific dimension(s) of the preschool language-learning environment is instrumental to advancing children’s language growth. In addressing this goal, we focus specifically on early childhood classrooms serving children from low-income homes. Because children from low-income homes often exhibit significant gaps in their language skills relative to more advantaged peers, the preschool classroom environment can be especially important for supporting their language acquisition ([LoCasale-Crouch et al., 2007](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0180)). Thus, the results of this work may be extremely relevant to settings that serve children from disadvantaged backgrounds.

There are significant practical implications for improving our understanding of the language-learning environments of early-education settings, and whether there are specific malleable dimensions of the environment that seem especially influential to children’s language growth. For instance, some studies have suggested that teachers’ use of questions and comments when interacting with children are especially important ([Girolametto & Weitzman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0085)). Professional-development offerings, teacher-education coursework, and published curricula draw upon such findings to provide evidence-based guidance to educators who work in early-education settings. For instance, one professional development program offered to early educators heavily emphasized the use of teacher questions as a way to improve children’s language in the classroom ([Powell, Diamond, Burchinal, & Koehler, 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0240)). Although trained teachers improved in their use of this language-facilitating strategy, it appeared to have little benefit to children’s language growth over time ([Powell et al., 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0240)). The present study is likely to have direct bearing on the types of strategies we encourage teachers to use in their classrooms, by pin-pointing those dimensions of the classroom environment that positively affect children’s language growth.

**1.2. Frequently examined dimensions of early-education classrooms**

**1.2.1. Linguistic responsivity**

The first dimension of the early-education environment examined in this study was caregivers’ linguistic responsiveness. From a language-facilitation perspective, linguistic responsivity is observed when adults are sensitive to and reflective of the child’s interests and/or utterances during conversations, often referred to as “following the child’s lead” ([Girolametto & Weitzman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0085)). For instance, when looking at a book together, an adult can be linguistically responsive by expanding the child’s utterance (child: “bug”, mother: “it’s a big bug!”) rather than diverting the child’s focus to something else in the book (child: “bug”, mother: “look at this mouse!”); such behaviors are referred to variously as expanding, extending, recasting, and contingent responding ([Landry et al., 2006](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0175); [Landry, Smith, Swank, Assel, & Vellet, 2001](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0170); [Tamis-LeMonda, Bornstein, & Baumwell, 2001](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0280)). Importantly, the frequency with which mothers and teachers use linguistically responsive behaviors during interactions has been linked to children’s language growth over time ([Cabell, Justice, McGinty, DeCoster, & Forston, 2015](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0035); [Landry et al., 2006](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0175); [Nicely, Tamis-LeMonda, & Bornstein, 1999](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0225); [Yoder & Warren, 1999](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0305)).

Adults’ responsivity behaviors can be differentiated into those behaviors that serve to promote children’s engagement in communication routines, referred to as communication-facilitating behaviors, and those that seek to provide advanced linguistic models, referred to as language-developing behaviors ([Girolametto, Pearce, & Weitzman, 1996](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0090); [Girolametto & Weitzman, 2002; Piasta et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0085)). The former, communication-facilitating behaviors, are specific behaviors that adults use to create and sustain children’s participation in multi-turn conversations and time spent in joint engagement. When engaging in extended periods of conversation with young children, adults often have to take an active role in maintaining the interaction, such as looking at the child expectantly to encourage him to contribute or to ask open-ended questions to cue a conversational turn ([Adamson, Bakeman, & Deckner, 2004](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0005)). In preschool settings, the frequency with which teachers are observed to use these strategies is associated positively with the complexity of children’s talk during interactions with their teachers ([Girolametto & Weitzman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0085)) as well as children’s vocabulary growth during an academic year ([Cabell et al., 2015](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0035)). The latter, language-developing behaviors, represent responsivity behaviors that serve to model for children advanced forms of language. Perhaps the most well-studied language-developing behaviors are recasts and expansions, in which an adult responds to a child’s utterance with a more syntactically (recast) or semantically complex (expansion) form ([Fey, Cleave, Long, & Hughes, 1993](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0080)).

Experts offer several reasons why linguistic responsivity serves to stimulate language growth among young children. First, with respect to communication-facilitating behaviors, experts suggest that these responsive behaviors allow the child to maintain rather than shift her current attentional focus, thus maximizing the allocation of cognitive resources towards the child’s current attentional allocation ([Landry et al., 2006](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0175)). Additionally, these responsive behaviors enhance the child’s understanding of the intentional nature of communicating (i.e., that talking to another recruits their interest and engagement), which serves to motivate the child to talk more often ([Yoder & Warren, 1999](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0305)). Second, with respect to language-developing behaviors, especially recasts and expansions in which adults extend children’s utterances with syntactically or semantically complex forms, experts argue that these provide children with a direct contrast between the child’s form and the adult’s more complex form ([Proctor-Williams & Fey, 2007](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0245)). Because the adult’s extension maintained the child’s referential focus, thus limiting working memory demands, the child’s attentional resources can focus on processing distinctions in the adult’s form. Such theories are important for interpreting the considerable empirical evidence indicating that adult use of communication-facilitating and language-developing strategies are beneficial to young children’s language development within various early caregiving settings, including both home and preschool settings.

**1.2.2. Data-providing features of teacher talk**

The second dimension of children’s language-learning environment examined in this study is the “data-providing features” of adults’ talk when interacting with children ([Hoff, 2003; Hoff & Naigles, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0140); [Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0145)). Data-providing features of input are relatively granular aspects of adult talk that provide children with crucial information about linguistic forms and functions. From a very young age, children employ biologically endowed computational processes to the input to which they are exposed, often referred to as statistical learning ([Marcus, Vijayan, Rao, & Vishton, 1999](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0195); [Saffran, 2003; Saffran & Wilson, 2003](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0265)). These processes allow children to extract information from their environment to acquire a seemingly infinite range of linguistic forms and functions that are never directly taught to them, such as marking verbs for tense and marking nouns for plurality.

Crucial for such processes is that the environment provide a sufficient corpus of data (i.e., input) for the child to analyze, including a sufficient number of different word types and syntactic forms ([Hoff & Naigles, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0135)). Indeed, variability in these data-providing features of adult talk within the home environment is associated with young children’s development of both vocabulary and grammar. For instance, [Hoff (2003)](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0140) showed that the number of different words mothers used when talking with their 2-year-olds was positively associated with children’s vocabulary skills (*r* = 0.22), whereas [Huttenlocher et al. (2002)](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0145) found that the percentage of syntactically complex sentences parents produced when talking with their 4-year-olds was positively associated with children’s grammar skills (*r* = 0.39). Within the early education classroom, studies find that data-providing features of teachers’ talk are associated with children’s growth in complex syntax, such as comprehension of syntactically complex sentences ([Huttenlocher et al., 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0145)). A recent study sought to explore the mechanisms by which the data-providing features of teachers’ talk, especially teachers’ expression of syntactically complex forms, may serve to accelerate children’s language development in the preschool classroom ([Justice et al., 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0155)). This work found significant, strong contingencies between teacher and child talk during small-group interactions, such that when teachers produced a syntactically complex utterance, children often followed with complex utterances of their own. These contingencies may provide the mechanism through which children internalize more syntactically advanced forms.

**1.2.3. System-level general quality of teacher–child interactions**

The third dimension of children’s early language-learning environment examined in this study is the systems-level, general quality of teacher-child interactions ([Hamre, Hatfield, Pianta, & Jamil, 2014](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0125)). This dimension has largely surfaced as the result of a measurement model designed to examine the general quality of children’s early education settings ([Hamre et al., 2014](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0125)). The need for such a measurement model is based on the increasingly large number of preschool-aged children enrolled in center-based care, often featuring an adult-child ratio of about 1 adult to 10 children. As preschool participation has grown, researchers and policy-makers have sought tools that differentiate lower- from higher-quality programs, especially in reference to children’s outcomes, including language development.

Measurement models that seek to represent the systems-level, general quality of the classroom environment appropriate the framework that teacher-child linguistic interactions are a key proximal process through which children’s language skills are developed in preschool settings ([Hamre et al., 2014; NICHD Early Child Care Research Network, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0125)). However, these measurement models do not serve to precisely catalog the fine-grained, granular proximal processes of teacher-child interactions, but rather index the overall quality of the classroom environment. Derived initially from the work of the [NICHD Early Child Care Research Network (2002)](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0220), and then second-generation tools derived from this work, especially the *Classroom Assessment Scoring System* (CLASS; [Pianta, Karen, Paro, & Hamre, 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0230)), there is currently a heavy reliance on using systems-level indices to represent the general quality of the language-learning environment available within early education settings ([Hamre et al., 2014; Mashburn et al., 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0125)). Application of the CLASS in early education settings serves to provide a general estimate of the linguistic environment based on the Language Modeling subscale of the tool or the composite of three subscales which collectively capture the level of Instructional Support in a classroom. For both the subscale and the composite, classrooms receive an overall score on a basic 1- to 7-point scale to delineate the overall level of the linguistic environment made available to children, and classrooms can be differentiated into those that provide low, average, and high levels of quality ([Burchinal, Vandergrift, Pianta, & Mashburn, 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0020)).

In recent years, the use of a general index to document classroom quality, including the quality of the language-learning environment, has gained considerable appeal as a professional development tool for teachers ([Hamre et al., 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0115)), a component of quality rating systems in the child-care system ([Sabol & Pianta, 2015](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0255)), and even for determining whether early education programs should continue to receive federal funding ([Mashburn, 2016](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0205)). Early evidence suggested that general systems-level scores of the preschool classroom were correlated with children’s language growth, suggesting the validity of this approach to representing the quality of children’s language-learning environment ([Mashburn et al., 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0200)). However, recent meta-analytic work has raised questions not only about the consistency of such effects but also the size of the relations linking general estimates of quality to children’s language outcomes. Such work shows that the relation between CLASS scores and children’s language development are so small that they have little to no practical value ([Keys et al., 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0160)). Current research therefore suggests that this third dimension of the language-learning environment, namely a systems-level general index of classroom quality, may insufficiently relate to children’s language growth over time.

**1.3. Purpose of this study**

The present study was designed to substantially increase our understanding of preschool classrooms as language-facilitating contexts for young children, with an interest in (1) exploring how best to represent the dimensionality of the classroom linguistic environment that preschool-aged children experience, and (2) determine those dimension(s) that are most strongly associated with children’s language-development trajectories. For our purposes, the three theorized dimensions of the preschool classroom’s linguistic environment were teachers’ linguistic responsivity (communication-facilitating behaviors and language-developing behaviors), data-providing features of teachers’ talk, and systems-level general classroom quality. Two questions were addressed. First, is the preschool classroom linguistic environment best represented as one dimension (uni-dimensional), two dimensions (bi-dimensional) or three dimensions (tri-dimensional)? Second, of the identified dimension(s), which is most strongly associated with children’s language growth over time?

**2. Method**

**2.1. Participants**

This study involved teachers and children in 49 preschool classrooms from a single mid-Atlantic state, all of which prioritized enrollment for children from low-income settings; 37 of the classrooms were affiliated with Head Start, and 12 were sponsored by the state pre-kindergarten initiative. The classrooms were enrolled in a larger experimental study involving evaluation of the effects of professional development (PD) on children’s language and literacy skills ([Cabell et al., 2011](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0030)). Classrooms were randomly assigned to a professional development (PD) group or a placebo control group. In the former, teachers received training on how to use specific strategies to facilitate children’s language skills, whereas in the latter teachers received training focused on creative ways to use the block center in their classrooms. This assignment should not have affected the dimensionality of the classroom environment nor the longitudinal relations between these dimensions and children’s language growth. Further, the PD had only modest effects on teachers’ practices ([Piasta et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0235)) and little discernable effects on children’s language growth ([Cabell et al., 2011](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0030)). Therefore, for the purpose of the present study, we include all 49 classrooms irrespective of study condition.

The lead teachers in these classrooms were primarily female (96%), and 67% were Caucasian. Of the remainder, 22% were Black, 2% were Native American, and 4% were multiracial (4% unreported). The majority of teachers (92%) had a two-year degree or higher (37% Associate’s, 33% Bachelor’s, 22% Master’s), although 4% held only a high school diploma (4% unreported). On average, teachers had about 12 years of teaching experience (*M* = 11.8 years, *SD* = 7.4). The majority of teachers (*n* = 44) reported using *The Creative Curriculum for Preschool* ([Dodge, Colker, & Heroman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0050)) as their primary classroom curriculum.

For the purposes of the larger study, a random sample of children within each classroom was selected to participate in ongoing study assessments during the fall and spring of the preschool year and then one-year later, when most children were in kindergarten. To randomly select these children, caregiver consent was solicited for all children in each classroom who met an age eligibility criterion of 3 years, 4 months by October of the study year. From among those children for whom consent was received, five to eight children per classroom were randomly selected. The exact number of children selected per classroom was based on the number of consents received; more children were selected from classrooms with higher consent rates.

The final sample of 330 children was well-balanced with respect to gender (174 males and 156 females) and relatively diverse (45% Caucasian, 33% African American, 5% Hispanic/Latino, with 16% multiracial, other, or unreported). The children were between 40 and 60 months of age (*M* = 52 months, *SD* = 5.5) at the start of the study. Noted previously, all children resided in low-income households based on eligibility for participating in the preschool programs. Data provided by primary caregivers (79% reporting) indicated that the majority of children (56%) lived in households with an annual income of less than $25,000 (55.5%), and the majority of mothers had limited educational attainment (70% did not complete high school or high school was highest degree earned). About 16% of children had identified disabilities.

**2.2. Procedure**

Classrooms and teachers were recruited into the study in the spring or summer prior to the academic year. Teachers agreed to participate in the study for a one-year period, with study activities including random assignment to a PD condition or control and ongoing observations in their classrooms, including videotaping. Children were enrolled into the study in the fall of the year, and participated in three assessment batteries over an approximately 20-month period: fall of preschool, spring of preschool, and spring of the following year.

The experimental procedures of the larger study involved provision of PD to teachers in a treatment group (*n* = 25) or a placebo control of PD on neutral topics for those in the control group (*n* = 24). In total, teachers received about 17 h of PD via a fall workshop (13 h) and a winter refresher (4 h). Those in the treatment group received training on how to use specific strategies in their classrooms to facilitate children’s language skills; the PD is detailed extensively under separate cover (see [Piasta et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0235)). Teachers in both groups were required to videotape themselves interacting with small groups of children in their classrooms every two weeks and submit these via stamped, addressed mailers to project staff. The videos were to be approximately 30 min in duration, and teachers were given instructions in how to capture these (e.g., how to set up the camera, target group size of children) and all materials needed for implementation (i.e., camera, tripod, recording media, mailers). Teachers were permitted to keep the camera and tripod following the study, thus providing an incentive for study participation and collecting/submitting the videos to project staff.

**2.3. Measures**

The primary measures utilized in the current study included assessment of children’s language skills and of the language environment of children’s preschool classrooms, representing three theorized dimensions: teachers’ linguistic responsivity, data-providing features of teachers’ talk, and systems-level general quality. An overview of these study measures, including a timeline for implementation, appears in [Table 1](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0005). For each measure of language environment, average scores across all available time points were used in the analyses.

Table 1. Variables used in main analyses with time-points.

|  |  | **Y1 fall** | **Y1 winter** | **Y1 spring** | **Y2 spring** |
| --- | --- | --- | --- | --- | --- |
| Children’ Language Skills | | | | | |
| Grammar | CELF-Sentence Structure (SS) | x |  | x | x |
|  | CELF-Word Structure (WS) | x |  | x | x |
| Vocabulary | CELF-Expressive Vocabulary (EV) | x |  | x | x |
|  | PPVT-3 (Receptive Vocabulary) | x |  | x | x |
|  | | | | | |
| Preschool Classroom Linguistic Environment | | | | | |
| Teachers’ Linguistic Responsivity | Communication strategies (CS) | x | x | x |  |
|  | Language developing strategies (LDS) | x | x | x |  |
| Data-Providing Features of Teachers’ Talk | Mean length of utterance (MLU) | x | x | x |  |
|  | Number of different words (NDW) | x | x | x |  |
|  | Percentage of complex sentences (Comp) | x | x | x |  |
|  | Noun phrase (NP) | x | x | x |  |
| Systems-Level General Environment | Concept development (CD) | x |  | x |  |
|  | Quality of feedback (QF) | x |  | x |  |
|  | Language modeling (LM) | x |  | x |  |

**2.3.1. Children’s language skills**

Two standardized measures were used to assess children’s language skills in the domains of morphosyntax and vocabulary: the Clinical Evaluation of Language Fundamentals—Preschool (CELF; [Wiig, Secord, & Semel, 2004](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0300)) and the Peabody Picture Vocabulary Test (PPVT; D. [Dunn & Dunn, 2007](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0060)). Children were administered these measures in one-on-one sessions with project staff in a quiet location in their program buildings. Prior to working in the field, project staff completed a multi-pronged training program to ensure the quality of their implementation of the measures.

The three core subtests of the CELF P-2 were administered: Sentence Structure, Word Structure, and Expressive Vocabulary. For Sentence Structure, children are provided with increasingly complex sentences and are asked to identify on a test plate which of four pictures best illustrates the given sentence. The subtest is designed to determine children’s knowledge of increasingly complex syntactic structures. For Word Structure, the examiner uses a cloze procedure to elicit target morphemes from children (e.g., the plural marker); the subtest is designed to assess children’s knowledge of inflectional and derivational morphology. For Expressive Vocabulary, children are shown a set of illustrations on test plates and are asked to provide the name of the item depicted; the subtest is designed to examine single-word, expressive vocabulary breadth. For all three subtests of the CELF P-2, test developers report test-retest reliability coefficients of 0.78–0.90 and internal consistency (i.e., Cronbach’s alpha and split-half reliability) ranging from 0.78 to 0.87 ([Wiig et al., 2004](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0300)). As an additional measure of vocabulary, the PPVT-III was also administered. In this assessment, children choose the illustration of four alternatives that best matches a target word spoken by the examiner. The measure is designed to assess single-word receptive vocabulary breadth. Test developers report an internal consistency of 0.95 (Cronbach’s alpha) and 0.94 (split-half reliability) as well as test-retest reliability for different age samples ranging from 0.91 to 0.94 ([Dunn & Dunn, 1997](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0055)). [Table 2](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0010) displays the descriptive statistics of each individual measure at the three time-points.

Table 2. Descriptive data for language measures at three time-points.

| **Measure** | **Y1 Fall** | | | **Y1 Spring** | | | **Y2 Spring** | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***M*** | ***SD*** | ***Range*** | ***M*** | ***SD*** | ***Range*** | ***M*** | ***SD*** | ***Range*** |
| CELF Sentence Structure | 10.31 | 4.82 | 0 to 22 | 13.57 | 4.83 | 0 to 22 | 16.89 | 3.97 | 1 to 22 |
| CELF Word Structure | 9.62 | 5.14 | 0 to 21 | 12.87 | 5.55 | 0 to 23 | 16.61 | 4.50 | 3 to 24 |
| CELF Expressive Vocabulary | 14.03 | 7.93 | 0 to 34 | 19.00 | 8.60 | 0 to 37 | 25.84 | 7.17 | 6 to 40 |
| PPVT Receptive Vocabulary | 42.07 | 19.12 | 1 to 86 | 54.31 | 19.98 | 3 to 100 | 72.53 | 18.47 | 10 to 136 |
| Grammar scaled composite | 0.00 | 1.00 | −2.20 to 2.36 | 0.73 | 1.07 | −2.09 to 2.68 | 1.51 | 0.83 | −1.54 to 2.89 |
| Vocabulary scaled composite | 0.00 | 1.00 | −2.05 to 2.16 | 0.65 | 0.74 | −2.14 to 2.81 | 1.65 | 0.91 | −1.40 to 4.07 |

*Note*: CELF = Clinical Evaluation of Language Fundamentals ([Wiig et al., 2004](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0300)); PPVT = Peabody Picture Vocabulary Test-III ([Dunn & Dunn, 1997](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0055))

For the purpose of this study, a composite score of grammar was created by scaling and averaging scores of CELF Sentence Structure and Word Structure (*r* = 0.629, 0.709, and 0.558 at each time point). Similarly, a composite vocabulary score was computed based on CELF Expressive Vocabulary and PPVT-III (*r* = 0.800, 0.734, and 0.722 at each time point). We used these composite scores to represent two key elements of language skills, namely grammar and vocabulary, in investigating the relationship between language environment and children’s language development.

**2.3.2. Teachers’ linguistic responsivity**

Teachers’ linguistic responsivity was assessed using an interval-based coding scheme designed to document teachers’ use of nine responsivity behaviors derived from the *Teacher Interaction and Language Rating Scale* (TILRS; [M. Girolametto, Weitzman, & Greenberg, 2000](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0095)). The TILRS was developed by its authors as a tool to assess teachers’ and parents’ conversational responsivity when interacting with toddlers and preschoolers (see [Girolametto et al., 2000](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0095)). A global rating scale in which observers rate adults’ use of responsivity strategies on a scale of 1 to 7 (e.g., “Wait and listen,” 1 = almost never, 7 = consistently), the primary use of this tool was to help coaches work with teachers and parents to improve their use of these strategies when interacting with their children. For the purposes of the larger study (see [Piasta et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0235)), the items in the TILRS (e.g., Wait and listen; Use a variety of questions.) were more explicitly codified and adapted to an interval-coding approach. This allowed coding of teachers’ responsive behaviors to occur with greater measurement precision as well as a high level of inter-rater reliability.

In total, teachers’ use of nine responsivity behaviors were coded for three videos submitted by teachers during week 2, week 14, and week 24 of the project and thereby spanning the academic year (three teachers failed to submit the week 24 video; therefore, we substituted their previously submitted video from week 22). During these videos, teachers were interacting with a small group of up to six children in their classroom using materials provided by the project (play-doh and related manipulatives). Although each video lasted up to 30 min in duration, we coded a medial randomly selected segment per video segmented into 15 30-s intervals. Each interval was coded for teachers’ use of each of nine responsive behaviors: (1) looking expectantly and being warm and receptive to encourage interaction; (2) using a slow pace of conversation to allow children to participate; (3) using comments to cue children to take turns; (4) using open-ended questions to stimulate conversation; (5) facilitating peer-to-peer communication; (6) stressing and/or repeating words to make them salient; (7) repeating and/or expanding children’s utterances; (8) using comments and questions to expand the discussion of certain objects or topics; and (9) using comments and questions to talk about feelings, to pretend, and/or to talk about the past or future. Each of these nine behaviors represented a distinct item on the coding scheme and was carefully defined in a coding catalog.

To conduct coding, the selected interval was divided into 15 30-s intervals and each was scored for the presence (1) or absence (0) of the 9 behaviors; an interval could be coded for multiple strategies. Coding was conducted by research staff who were trained to 90% accuracy of coded intervals on master-coded video segments. A randomly selected 10% of videos were double-coded, and exact agreement across the double-coded sessions was 88%. Scores per behavior were averaged across intervals, to account for intervals that could not be coded due to poor video or audio quality.

As part of the scale adaption, we re-examined the reliability and validity of the nine items as coded in the present study. In doing so, we dropped two items that had low correlation with all the other items (item 3, 6), and validated the factor structure for the remaining seven items using factor analyses. The seven behaviors represent two sets of strategies, which we refer to as communication-facilitating and language-developing strategies, consistent with prior descriptions of the TILRS items (see [Piasta et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0235)). *Communication-facilitating strategies* are those that teachers use to encourage and maintain classroom conversation (e.g., teacher uses open-ended questions to stimulate conversation; items 1, 2, 4, 5), whereas *language-developing strategies* are those that teachers use to teach children new language forms or functions, primarily by commenting and expanding (e.g., teacher expands child utterance; items 5, 7, 8, 9). Note that item 5 (facilitating peer-to-peer communication) loaded on both factors. Scale validation information is provided in [Table 3](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0015). For our purposes, the extracted factor scores of communication-facilitating and language-developing strategies were used in analyses.

Table 3. Validation of the adapted Teacher Interaction and Language Rating (TILR) Scale.

|  |  | **Communication Facilitation** | **Language Developing** |
| --- | --- | --- | --- |
| Standardized Item Loadings | 1. looking expectantly and being warm and receptive to encourage interaction | 0.797\*\*\* |  |
| 2. using a slow pace of conversation to allow children to participate | 0.649\*\*\* |  |
| 3. using comments to cue children to take turns (dropped) |  |  |
| 4. using open-ended questions to stimulate conversation | 0.431\*\* |  |
| 5. facilitating peer-to-peer communication | 0.332\* | 0.564\*\*\* |
| 6. stressing and/or repeating words to make them salient (dropped) |  |  |
| 7. repeating and/or expanding children’s utterances |  | 0.685\*\*\* |
| 8. using comments and questions to expand the discussion of certain objects or topics |  | 0.321\* |
| 9. using comments and questions to talk about feelings |  | 0.378\* |
| CFA Model Fit | Chi-square test | <βρ>χ2 = 10.185, *df* = 12, *p* = 0.600 | |
| RMSEA | 0.000, 90% CI = (0.000, 0.127) | |
| CFI | 1.000 | |
| SRMR | 0.064 | |

\**p* < 0.05; \*\* *p* < 0.01; \*\*\* *p* < 0.001.

**2.3.3. Data-providing features of teachers’ talk**

The same three videos used to examine teachers’ responsivity were also coded to examine the data-providing features of teachers’ talk with children. As noted previously, the three videos coded corresponded to those taken at the beginning (week 2), middle (week 14), and end (week 22 or 24) of the year. Coding of the data-providing features of teachers’ talk involved first developing a transcript of the small-group interaction captured in each video. To develop this transcript, a 10-min segment was selected from the mid-point of each video for transcription. The segment was slightly longer than that used to capture teachers’ conversational strategies so to ensure an optimal corpus of utterances and words to analyze, given that some strategies involve teachers talking less rather than more (e.g., looking expectantly to encourage a child to talk). Other researchers have used 10-min video segments as a means to assess preschool teachers’ conversational strategies ([Girolametto & Weitzman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0085)), finding that these provide adequate information about teachers’ talk to examine its relations to children’ language skills. Any videos that were less than 10 min in length (44%) were coded in their entirety.

Transcription was conducted using the Systematic Analysis of Language Transcripts software for Windows (SALT; Version 9). Parsing occurred at the level of the T-unit and adhered to SALT conventions for marking morphemes, addressing fillers and mazes, and accounting for unintelligible utterances and interruptions. Each T-unit, consisting of no more than two independent clauses with dependent clauses or attached phrases, was entered as a separate line in the SALT software. Transcription was conducted by research assistants who had completed a multi-step tutorial involving completion of practice transcripts and a reliability test. The reliability test involved achieving 90% agreement against four master-coded transcripts, with agreement calculated separately for accuracy of (1) T-unit segmentation, (2) word-for-word transcription, and (3) SALT conventions and codes. Additionally, a subset of videos (10%) was independently transcribed to assess inter-rater reliability among the trained coders. We calculated the correlations between the doubly-transcribed sessions to examine relations for all SALT standard measures, including total number of utterances, mean length of utterance in words and morphemes, type-token ratio, number of different words, and number of bound morphemes; correlations ranged from 0.89 to 0.99.

When transcribing, coders inserted codes into each teacher T-unit to capture the complexity of each T-unit in terms of its clausal complexity and noun phrase density, using a scheme adapted from [Huttenlocher et al. (2002)](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0145). To code the clausal complexity of each T-unit, each was assigned a mutually exclusive code to document whether the T-unit contained no clauses (NO; e.g., “that boy”), one clause (SIMPLE; e.g., “the boy is coming”), or multiple clauses (COMPLEX; e.g., “the ball fell and I’ll pick it up”). The coding system used, with additional examples, is described in prior reports ([Justice et al., 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0155)). In addition, coders also inserted codes into each T-unit to document each instance of a noun phrase (NP). The coding of NP was based on [Huttenlocher et al. (2002)](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0145), which served to identify the number of NPs per T-unit in maternal speech. For instance, the T-unit “Juan, you need to put that down and help Xavier with his truck” would be coded to contain five noun phrases based on the scheme presented in Huttenlocher et al. [“Juan (NP), you (NP) need to put that (NP) down and help Xavier (NP) with his truck (NP)”].

The SALT software was used to automatically generate four measures of teachers’ data-providing features. The first two measures are standard calculations computed by the software: mean length of utterances in morphemes (MLU) and total number of different words (NDW). MLU represents the average number of morphemes per T-Unit for teachers. NDW represents the total number of different word roots produced. In addition, using the COMPLEX and NP codes inserted into each T-unit, we calculated a measure of T-unit complexity (COMP) by dividing the number of T-units with the COMPLEX code by the total number of utterances per transcribed observation. The COMP index per each transcript indicates the percentage of teacher T-units that were complex (i.e., contained multiple clauses). In addition, we calculated a measure of noun phrase (NP) by counting the total number of NPs coded per observation. In total, four data-providing features of teachers’ talk were used in analyses: MLU, NDW, COMP, and NP.

**2.3.4. Systems-level general environment**

The systems-level general environment was measured at two timepoints (fall, spring) via direct observation of each classroom using the CLASS ([Pianta et al., 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0230)). The CLASS is an observational tool designed to capture general qualitative features of the classroom environment, with a focus on the quality of the interactions among teachers and children. The CLASS is often viewed as an index of general classroom quality ([Mashburn et al., 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0200)). The tool is organized to capture three domains of classroom quality (Emotional Support, Instructional Support, Classroom Organization), each of which is represented by three or four more specific dimensions; in total, 10 domains are examined (e.g., Positive Climate, Teacher Sensitivity). To administer the CLASS, observers rate each of the 10 dimensions on a holistic 7-point coding scheme for which 1 = low and 7 = high.

For the current study, field assessors conducted two-hour videotaped classroom observations in the fall and spring of the preschool year. To select the optimal time for the observation, project staff worked with teachers to identify an observational period that represented a customary day and during which a range of typical classroom routines could be observed. To conduct coding of the ten dimensions, three 20-min cycles were randomly chosen from each videotaped observation to be coded by trained and reliable CLASS coders. The codes for each cycle are then averaged for each of the ten dimensions to arrive at a score for each classroom at each time-point. To ensure the reliability of the CLASS coding, 20% of the cycles were randomly selected for double-coding by two independent observers, and the intraclass correlations for double-coded video segments were examined using a two-way mixed model across all project time-points and cohorts; all ICCs exceeded 0.7 for all domains.

For the present study, we used the three dimensions of the CLASS that comprise the Instructional Support domain (Concept Development, Quality of Feedback, Language Modeling), as these are designed to capture systems-level, general interactions supportive of children’s language growth ([Justice, Mashburn, Hamre, & Pianta, 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0150)), and prior work has shown that the Instructional Support domain is positively associated with children’s language growth in pre-kindergarten settings ([Mashburn et al., 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0200)). The Concept Development dimension is designed to capture the extent of instructional discussions and activities that promote children’s higher-order language and cognition skills, such as opportunities to compare/contrast, reason, and problem solve. (All descriptions of dimensions are derived from the CLASS coding manual; [Pianta et al., 2008](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0230)). The Quality of Feedback dimension captures the extent to which teachers provide quality feedback to children that serves to expand their learning, including the extent to which teachers and children engage in back-and-forth exchanges and teachers provide responsive feedback to children. The Language Modeling dimension captures the extent to which teachers provide children with a language-stimulating environment, including the extent to which teachers ask children open-ended questions, engage in multi-turn conversations, and repeat and extend children’s conversational contributions.

For the present study, ratings were averaged across the two time points for each dimension. Mean scores for each time-point are shown in [Table 4](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0020).

Table 4. Descriptive data for the linguistic environment measures.

| **Construct** | **Specific Index** | **Y1 fall** | **Y1 winter** | **Y1 spring** | **Y1 mean** |
| --- | --- | --- | --- | --- | --- |
|  |  | **M (SD)** | **M (SD)** | **M (SD)** | **M (SD)** |
| Data-Providing Features of Teachers’ Talk | Mean length of utterance (MLU) | 5.85 (0.98) | 6.20 (0.91) | 6.20 (1.11) | 6.05 (0.83) |
| Number of different words (NDW) | 186.02 (39.58) | 188.84 (38.74) | 187.71 (45.21) | 186.34 (29.62) |
| Percent complex sentences (COMP) | 0.28 (0.11) | 0.31 (0.09) | 0.29 (0.09) | 0.30 (0.13) |
| Noun phrase (NP) | 62.93 (33.05) | 71.21 (27.50) | 63.24 (26.66) | 63.93 (19.64) |
| Systems-Level General Environment | Concept development (CD) | 2.91 (1.66) |  | 2.40 (1.48) | 2.66 (1.25) |
| Quality of feedback (QF) | 3.00 (1.31) |  | 3.54 (1.66) | 3.27 (1.30) |
| Language modeling (LM) | 3.29 (1.53) |  | 3.54 (1.46) | 3.43 (1.22) |

**2.4. Analyses**

In order to examine the underlying dimension(s) of preschool classrooms’ linguistic environment, we employed exploratory structural equation modeling (ESEM) ([Asparouhov & Muthén, 2009](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0010)). Unlike conventional confirmatory factor analysis (CFA) that aims to test a parsimonious measurement model based on strong *a priori* substantive knowledge, ESEM allows for testing of a richer set of alternative, less restrictive models. While being exploratory in nature, ESEM also gives access to all the CFA features (e.g., correlated residuals, model fit indices, parameter constraints), offering a great amount of flexibility in the situation of model uncertainty. Considering that the dimensionality of the preschool classroom linguistic environment is yet unknown, we employed ESEM with oblique Geomin rotation ([Asparouhov & Muthén, 2009](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0010)) as a preferable exploratory approach over confirmatory analyses ([Browne, 2001](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0015)).

Following ESEM, we explored the predictive relationship between the dimensions of the classroom linguistic environment and children’s language skills using multilevel latent growth model ([Meredith & Tisak, 1990](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0210)). Trajectories of children’s grammar and vocabulary development from preschool to kindergarten were modeled using latent growth curves, the slope of which was predicted by classroom-level factor scores extracted from the final linguistic environment dimensionality model. While the preschool classroom effects are modeled at level-2, we did not include the clustering of kindergarten classrooms due to a high percentage of missing data (30%) of kindergarten classroom affiliation. This missing data is a result of the primary data collection occurring during children’s year of preschool participation.

Missing data ranged from 2% to 4% for teachers’ data-providing features, and 14% to 26% for children’s language measures. There was no missing data for measures of the general language environment or teachers’ responsivity. Instead of using listwise deletion, which tends to greatly reduce sample size and produce biased results ([Graham, 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0105)), we applied full information maximum likelihood (FIML) to incorporate all available information in each step of the analyses ([Enders, 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0070)). The final valid sample sizes were 49 classrooms and 320 children. All analyses were carried out using Mplus 7.11 ([Muthén & Muthén, 2005](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0215)).

**3. Results**

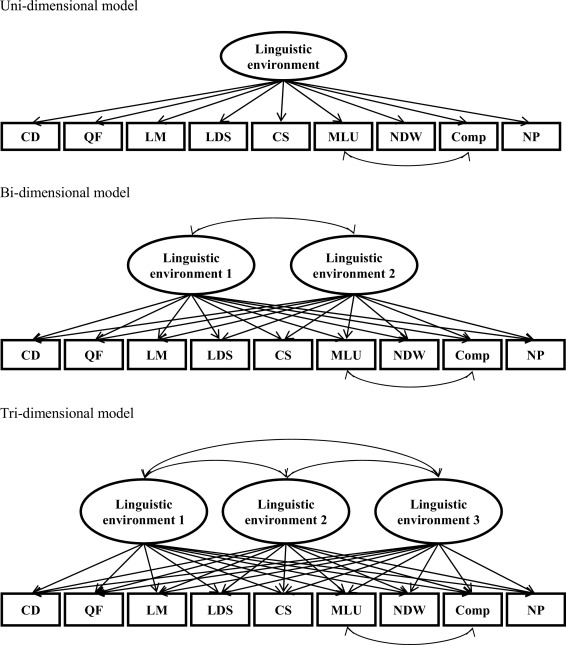
**3.1. Exploring dimensions of the classroom linguistic environment**

Pearson correlation coefficients between the nine observed indicators of the classroom linguistic environment are displayed in [Table 5](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0025). Using these indicators, we sequentially tested three ESEM models, representing uni-dimensional, bi-dimensional, and tri-dimensional structures respectively ([Fig. 1](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "fig0005); fit indices in [Table 6](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0030)). By *a priori* hypothesis, we co-varied MLU and percentage of complex sentences in every model, as these two variables representing data-providing features of teachers’ talk both captured attributes of an average utterance and were computed using the same denominator.

Table 5. Pearson’s correlation coefficients between measures of classroom linguistic environment (N = 49 classrooms).

|  | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1. Communication facilitation | – |  |  |  |  |  |  |  |
| 2. Language developing | 0.245 | – |  |  |  |  |  |  |
| 3. Mean length of utterance | −0.311 | 0.079 | – |  |  |  |  |  |
| 4. Number of different words | −0.063 | 0.226 | 0.531 | – |  |  |  |  |
| 5.% complex sentences | −0.043 | −0.038 | 0.584 | 0.268 | – |  |  |  |
| 6. Noun phrases | −0.203 | 0.177 | 0.583 | 0.689 | 0.396 | – |  |  |
| 7. Concept development | 0.027 | −0.024 | 0.113 | 0.244 | 0.118 | 0.041 | – |  |
| 8. Quality of feedback | −0.096 | 0.115 | 0.114 | 0.400 | 0.054 | 0.195 | 0.522 | – |
| 9. Language modeling | −0.020 | −0.031 | 0.100 | 0.339 | 0.183 | 0.157 | 0.576 | 0.761 |

*Note*: For each measure, scores are averaged across all available time points in preschool year.



1. [Download high-res image (707KB)](https://ars.els-cdn.com/content/image/1-s2.0-S0885200616301788-gr1_lrg.jpg)
2. [Download full-size image](https://ars.els-cdn.com/content/image/1-s2.0-S0885200616301788-gr1.jpg)

Fig. 1. Graphical representation of the alternative models tested in Exploratory SEM.

*Note*: CD = Concept development; QF = Quality of feedback; LM = Language modeling; LDS = Language developing strategies; Comm = Communication strategies; MLU = Mean length of utterance; NDW = Number of different words; Comp = Percentage of complex sentences; NP = noun phrases.

Table 6. Model fit of the ESEM models.

|  | **χ2 (df)** | ***p*** | **Δχ2 test** | **RMSEA** | **CFI** | **SRMR** | **AIC** | **BIC** | **ABIC** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 dimension | 89.643 (26) | <0.001 |  | 0.211 | 0.584 | 0.140 | 1194.619 | 1247.590 | 1159.725 |
| 2 dimension | 22.548 (18) | 0.209 | *p <*0.001 | 0.072 | 0.967 | 0.059 | 1150.525 | 1218.630 | 1105.660 |
| 3 dimension | 10.556 (11) | 0.481 | *p*= 0.101 | 0.000 | 1.000 | 0.035 | 1152.533 | 1233.881 | 1098.945 |

*Note*: RMSEA = Root mean square error of approximation; CFI = Comparative fit index; SRMR = Standardized root mean square residual; AIC = Akaike information criterion; BIC = Bayesian information criterion; ABIC = Sample-size adjusted Bayesian information criterion.

Results revealed that the preschool classroom language environment is best represented multi-dimensionally, as the uni-dimensional model did not fit the data well (χ2 = 89.64, *p* < 0.001; RMSEA = 0.211; CFI = 0.584; SRMR = 0.140). On the other hand, both the bi-dimensional and tri-dimensional models provided reasonable model fit (*p*-values of χ2 tests > 0.05; RMSEA < 0.08; CFI > 0.950; SRMR < 0.08) and offer significant improvement in fit as compared to the uni-dimensional model. The tri-dimensional model further boosted model fit compared to the bi-dimensional model (Δχ2 = 11.99, *p* = 0.101; ΔRMSEA = −0.072; ΔCFI = 0.033; ΔSRMR = −0.024; lower ABIC value). Interestingly, the tri-dimensional model indicated a similar structure as what was revealed in the competing bi-dimensional model. Specifically, the first dimension is dominated by measures of teachers’ data-providing features (MLU, NDW, Comp, and NP) along with the language-developing responsivity behaviors. The second dimension mostly represents the systems-level, general language environment as measured by concept development, quality of feedback, and language modeling. The third dimension represents teachers’ communication-facilitating responsivity behaviors exclusively, which do not load onto either factor in the bi-dimensional model, and they alone dominate a third factor in the tri-dimensional model. Therefore, we concluded from the model fit indices that our data best support a tri-dimensional structure for the preschool-classroom linguistic environment, consisting of data-providing and language-developing features of teachers’ talk (*teacher talk;* dimension 1), the systems-level general environment (*system-level quality*; dimension 2), and teachers’ communication facilitating behaviors (*communication facilitation*; dimension 3).

The factor loading pattern and factor correlations from the tri-dimensional ESEM model are displayed in [Table 7](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0035). The factor loading pattern reveals a clear three-dimension structure, in which each item loads highly onto one dimension while the loadings on the other two dimensions are relatively low (<0.30). Factor correlations are generally small (−0.084 to 0.188), implying that the three dimensions are distinct aspects of preschool classrooms’ linguistic environment.

Table 7. Standardized loading pattern and factor correlation of the tri-dimensional ESEM.

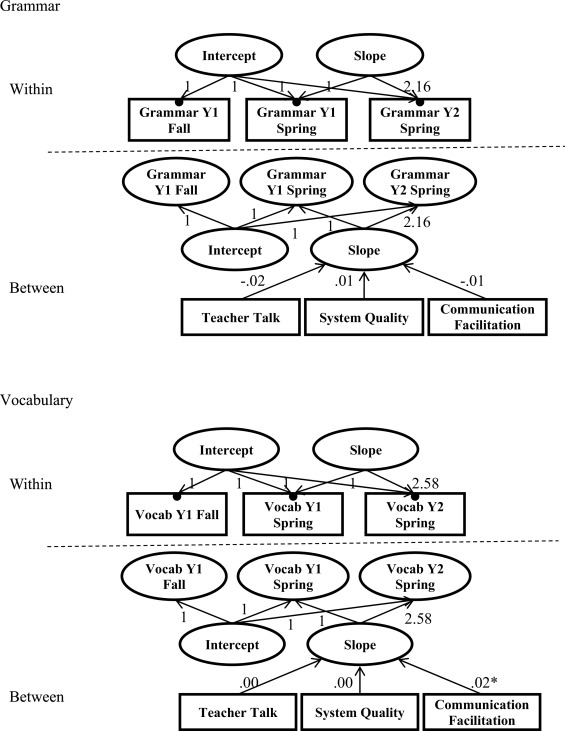
|  | **Teacher Talk** |  | **System-level Quality** |  | **Communication Facilitation** |  | **R2 (%)** |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **λ** | **S.E.** | **λ** | **S.E.** | **λ** | **S.E.** |  |
| Mean length of utterance | 0.631 | 0.102 |  |  |  |  | 49.0 |
| Number of different words | 0.790 | 0.098 |  |  |  |  | 75.8 |
| Percent of complex sentences | 0.339 | 0.155 |  |  |  |  | 13.5 |
| Noun phrases | 0.803 | 0.090 |  |  |  |  | 68.7 |
| Language developing strategies | 0.301 | 0.144 |  |  |  |  | 14.8 |
| Communication strategies |  |  |  |  | 0.999 | 0.001 | >99.9 |
| Concept development |  |  | 0.637 | 0.101 |  |  | 40.1 |
| Quality of feedback |  |  | 0.821 | 0.087 |  |  | 70.8 |
| Language modeling |  |  | 0.916 | 0.073 |  |  | 83.2 |
| Teacher Talk | – | |  |  |  | |  |
| System-level Quality | 0.188 | | – | |  | |  |
| Communication Facilitation | −0.084 | | −0.038 | | – | |  |

*Note*: The upper-part of the table contains the standardized loadings for each indicator, and the lower-part of the table contains the correlation coefficients between the three factors. For clarity in the table, cross-loadings below 0.30 are not displayed.

S.E. = Standard error.

**3.2. Dimensions of the linguistic environment and children’s language growth**

In order to explore how the multiple dimensions of the preschool linguistic environment are associated with children’s language-development trajectories, we employed multilevel latent growth models as depicted in [Fig. 2](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "fig0010). Analyzing grammar and vocabulary development separately, we hypothesized that children’s language development from fall of preschool to the spring of kindergarten year (three time-points) can be summarized with a latent growth curve, and that the growth rate (indicated by the latent slope) is potentially predicted by the three dimensions of linguistic environment, the scores of which were estimated as factor scores in the tri-dimension ESEM. Results of the latent growth models are summarized in [Table 8](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "tbl0040), and some of the coefficient estimates are marked in [Fig. 2](https://www.sciencedirect.com/science/article/pii/S0885200616301788#fig0010).



1. [Download high-res image (652KB)](https://ars.els-cdn.com/content/image/1-s2.0-S0885200616301788-gr2_lrg.jpg)
2. [Download full-size image](https://ars.els-cdn.com/content/image/1-s2.0-S0885200616301788-gr2.jpg)

Fig. 2. Latent growth models predicting children’s language development trajectories from preschool classroom’s linguistic environment.

Table 8. Parameter estimates of two-level latent growth models.

|  |  |  | **Grammar** | | | **Vocab** | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Coeff** | **SE.** | **p** | **Coeff** | **SE** | **p** |
| Parameter estimates | | | | | | | | |
| Within | Baseline (intercept) | Variance | 0.88 | 0.08 | <0.001 | 0.87 | 0.07 | <0.001 |
|  | Growth rate (slope) | Variance | 0.09 | 0.02 | <0.001 | 0.04 | 0.01 | <0.001 |
| Between | Baseline (intercept) | Mean | −0.01 | 0.07 | 0.903 | −0.01 | 0.08 | 0.897 |
| Baseline (intercept) | Variance | 0.04 | 0.05 | 0.489 | 0.14 | 0.05 | 0.006 |
| Growth rate (slope) | Mean | 0.69 | 0.06 | <0.001 | 0.62 | 0.04 | <0.001 |
| Growth rate (slope) | Variance | 0.00 | 0.01 | 0.838 | 0.01 | 0.01 | 0.034 |
| Teacher talk → slope | | −0.02 | 0.02 | 0.37 | 0.00 | 0.02 | 0.892 |
| System-level quality → slope | | 0.01 | 0.02 | 0.666 | 0.00 | 0.02 | 0.950 |
| Communication facilitation → slope | | −0.01 | 0.02 | 0.455 | 0.02 | 0.01 | 0.047 |
| Trajectory | Y1 fall to Y1 spring | | 1.00 | / | / | 1.00 | / | / |
| Y1 spring to Y2 spring | | 2.16 | 0.16 | <0.001 | 2.58 | 0.13 | <0.001 |
|  | | | | | | | | |
| Intraclass correlation (ICC) | | | | | | | | |
|  | Y1 Fall | | 0.088 | | | 0.142 | | |
|  | Y1 Spring | | 0.072 | | | 0.093 | | |
|  | Y2 Spring | | 0.034 | | | 0.101 | | |

*Note*: Coeff. = Coefficient (unstandardized); S.E. = Standard error.

For grammar, the intraclass correlations were 0.088, 0.072, and 0.034 for the three time-points respectively, indicating that 3.4% ∼ 8.8% of total variation in children’s grammar scores were attributable to classroom differences. The latent growth model had acceptable fit (χ2 = 16.01, df = 9, *p* = 0.067; RMSEA = 0.049; CFI = 0.984). The estimated growth in grammar was approximately 0.69 standard deviations (*SD*) in the preschool year as compared to baseline, and an extra 0.80 *SD* in kindergarten. However, the classroom-level growth rate was not predicted by any of the three dimensions of linguistic environment. In fact, with the majority of variation observed at the child level, and the very small variance of level-2 slope attributable to the classroom (coefficient = 0.00, *p* = 0.838), we could not expect to link any feature of the classroom linguistic environment to the growth of grammar.

For vocabulary, the intraclass correlations were 0.142, 0.093, and 0.101 for the three time-points respectively, indicating that 9.3%–14.2% of total variance in vocabulary scores were attributable to classroom differences. Again, fit was satisfactory for the latent growth model (χ2 = 10.84, df = 9, *p* = 0.287; RMSEA = 0.025; CFI = 0.997). On average, children’s vocabulary scores increased by 0.62 *SD* in the preschool year, and by 0.98 *SD* in the kindergarten year, demonstrating accelerating growth. Among the three dimensions of preschool linguistic environment, teachers’ communication-facilitating behaviors significantly predicted growth rate at the classroom level (coefficient = 0.02, *p* = 0.047). Specifically, with one unit increase in teachers’ use of communication-facilitating behaviors, the growth rate in vocabulary was expected to increase by 0.02 *SD*. On the other hand, teacher talk and systems-level general environment did not predict the classroom-level growth rate.

**4. Discussion**

Today, the majority of preschool-aged children in the United States attend center-based preschool programs in the years prior to kindergarten entrance. Many preschool programs, especially those supported by federal and state funds, include in their mission a goal to support children’s school readiness, including language development ([Scott-Little, Kagan, & Frelow, 2006](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0270)). Both theory and evidence support the need for preschool classrooms to provide linguistically rich environments to children in order to support their language growth over time ([Dickinson & Caswell, 2007; Dickinson & Smith, 1994](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0040)). Such work has generally emphasized three dimensions of the preschool classroom environment as being especially important: teachers’ linguistic responsivity when interacting with children ([Girolametto & Weitzman, 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0085); [Girolametto, Weitzman, & Greenberg, 2003](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0100)), the data-providing features available within teachers’ talk to children ([Huttenlocher et al., 2002; Justice et al., 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0145)), and the systems-level general quality of preschool classrooms ([Hamre et al., 2014](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0125)). While each of these proposed dimensions of the linguistic environment has been linked to growth in children’s language skills, the unique contribution of each has not been assessed. Identifying which of these dimensions appears most strongly associated with children’s language growth over time would have significant influence on educational practices and policies, as these might serve as the most important levers in the design of professional development (PD) and curricular programs and practices. In addition, such work could be highly informative to teacher-preparation programs that prepare educators to work in early-education settings.

The goal of the present study was to examine the dimensionality of the linguistic environment of 49 preschool classrooms, and assess the relations between the empirically determined dimensions and children’s longitudinal trajectories in vocabulary and grammar from preschool to the end of kindergarten. Although there was insufficient between-classroom variance in children’s grammatical development to link features of the classroom environment to growth in this domain of language, we found that one specific dimension of the preschool classroom linguistic environment was associated with children’s longitudinal growth in vocabulary, namely teachers’ use of communication-facilitating strategies. Here, we discuss this and additional findings of note as well as implications for educational practice.

The first finding of note in this study was establishing that the preschool classroom linguistic environment is best represented tri-dimensionally. Dimension 1, teacher talk, reflected the data-providing and language-developing features of teachers’ talk, including both the lexical diversity and grammatical complexity of their utterances. Dimension 2, system-level quality, reflected the general quality of the classroom environment with respect to instructional support; and Dimension 3, communication facilitation, reflected teachers’ use of specific facilitative behaviors that serve to engender children’s conversational participation. This finding helps us to recognize that the linguistic environment of preschool classrooms is multi-dimensional, and that the dimensions appear to reflect discrete aspects of the classroom environment, given the relatively low inter-dimensional correlations. For instance, two variables represented in Dimension 1, namely the mean length of utterances and percentage of syntactically complex utterances of teachers’ talk, both reflecting important data-providing features of teachers’ talk, were very modestly correlated with the systems-level general measure of quality represented by the Language Modeling subscale of the CLASS (*r* = 0.093 and 0.179, respectively). Similarly, teachers’ use of communication-facilitating behaviors, representing in part teachers’ linguistic responsivity when talking with children, was also poorly correlated with the Language Modeling subscale (*r* = 0.229). The importance of this finding is that it shows that the linguistic environment of preschool classrooms cannot be represented monolithically in empirical or theoretical discussions. Rather, it seems necessary to disambiguate the nature of teacher talk, the systems-level quality, and communication facilitating behaviors of the teacher, and as well to recognize that the systems-level quality measures often discussed in the literature ([Keys et al., 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0160))may not adequately index the more proximal processes represented by Dimension 1, Teacher Talk, and Dimension 3, Communication Facilitation.

In examining the dimensionality of the linguistic environment of preschool settings, it is worth noting that teachers’ linguistic responsivity, measured in terms of language-developing and communication-facilitating behaviors, do not represent a single unitary dimension. Rather, teachers’ language-developing behaviors, such as their use of recasts and expansions, loaded with data-providing features of teachers’ talk, such as the syntactic complexity of teachers’ utterances. Theoretically, this is an intriguing finding as it suggests that *functional* features of teachers’ talk that have long been believed to directly facilitate children’s language, such as expanding children’s utterances, share variance with the *grammatical properties* of teachers’ utterances, which are also viewed as facilitative of children’s language. It seems that features of teachers’ talk, whether functional forms (e.g., questions) or grammatical properties, that directly serve to provide children with advanced linguistic models represent a single dimension of children’s linguistic environment.

The second finding of note is that the dimension most strongly associated with children’s linguistic trajectories, specific to vocabulary, was teachers’ use of communication-facilitating behaviors. In fact, teachers’ use of these behaviors was the only significant predictor of vocabulary growth over time. We propose that the mechanism behind this finding is that the communication-facilitating behaviors measured in this study resulted in children talking more within the classroom, which directly facilitates children’s language development. That is, by using strategies to encourage children to talk more, teachers are able to directly facilitate children’s language growth. At the same time, these strategies also likely served to encourage children’s active participation in conversations, which has been shown to contribute to children’s growth in vocabulary ([Zimmerman et al., 2009](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0310)). Conversations can be especially important to children’s language development, as these provide a context in which adults can scaffold their interactions based on the children’s needs ([Konishi, Kanero, Freeman, Golinkoff, & Hirsh-Pasek, 2014](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0165)). The information provided by children’s talk may be even more relevant for adults in group situations such as classrooms, given the diversity in children’s language skills and the teacher’s need to adapt their language to different children at different times.

Another way in which communication-facilitating strategies could encourage vocabulary growth is by supporting the development of socio-cognitive skills that are crucial for language learning, such as joint attention ([Tamis-LeMonda, Kuchirko, & Song, 2014](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0285)). The episodes of joint attention created by communication-facilitation behaviors, such as following the child’s lead or waiting expectantly for children to respond, are key in helping children understand the intentional and communicative nature of language, and this understanding in turn can support children’s subsequent vocabulary acquisition. Joint attention, as well as other social cognition skills such as perspective taking and theory of mind, are seen as central to language acquisition in social-pragmatic accounts of word learning, since they expand the available information that children can use to identify the correct referent for a new word ([Butler & Tomasello, 2016](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0025); [Grassmann, Stracke, & Tomasello, 2009](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0110); [Tomasello & Akhtar, 1995](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0290)). Creating joint attention episodes that foster the development of social cognition skills may be more challenging in the classroom than in a dyadic parent-child situation, and therefore teachers’ ability to use communication-facilitating strategies become crucial.

However, none of these hypotheses about the role of communication-facilitating strategies can explain why the other aspect of responsivity evaluated in this study, language-developing behaviors, did not make a contribution to children’s vocabulary growth. It is possible that communication-facilitating strategies moderate the impact of other dimensions of classroom language. For example, language-developing strategies such as recasts and expansions may only have a positive impact when children participate and provide input for the adult to recast or expand. It is possible that in the absence of sufficient communication-facilitating behaviors, children do not develop the socio-cognitive skills necessary to benefit fully from linguistic input.

By demonstrating the potentially crucial contribution of teacher behaviors that actively cultivate children to communicate in the classroom, the results of this study help to elucidate why recent efforts to link systems-level general classroom quality measures to child language gains during preschool have not been successful. For instance, Keys and colleagues (2013) conducted a meta-analysis examining the relations between several systems-level preschool-classroom quality indices and children’s language growth which aggregated data from four large-scale studies. One of the four studies specifically employed the CLASS Instructional Support dimension, as we did in the present study, showing it to be only very modestly related to children’s language outcomes. The present results suggest that systems-level classroom quality measures may not adequately document the critical proximal processes that most contribute to children’s development in preschool settings.

In this regard, the present study also raises questions regarding some current directions for how to improve children’s language development in the preschool setting, specifically those which focus on improving the systems-level general environment through intensive professional development of teachers ([Early, Maxwell, Ponder, & Pan, 2017](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0065); [Hamre et al., 2012; LoCasale-Crouch et al., 2016](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0120)). The outcome of these studies is the CLASS observational tool, presumably because improvements in the systems-level general quality of the classroom environment will have downstream effects on children’s language skills, among other cognitive outcomes ([LoCasale-Crouch et al., 2016](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0185)). However, recent evidence shows that even very intensive professional development efforts delivered to preschool teachers are ineffective in increasing CLASS Instructional Support scores to the magnitude that likely is needed to improve children’s language skills, with increases typically in the range of about 0.1–0.3 of one point on the 7-point scale ([Early et al., 2017](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0065)). Rather, professional development efforts provided to early educators should focus most intensively on helping them to both elevate and execute the precise, proximal behaviors that serve to engage children in productive conversations.

While we were not particularly surprised to find that systems-level general features of the classroom environment would not correlate with children’s growth (see [Keys et al., 2013](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0160)), it is unexpected to find that the data-providing features of teachers’ talk did not have unique relevance for children’s language growth. Both theory and evidence point to the importance of very granular features of adults’ talk, such as the syntactic complexity of their utterances, to children’s growth in both grammar and vocabulary ([Hoff, 2003; Huttenlocher et al., 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0140)). There are several possibilities regarding our non-significant findings. First, prior research linking data-providing features of teachers’ talk to children’s language skills did not include other dimensions of the classroom linguistic environment; thus, the observed relations may have reflected the possible shared variance between data-providing features of teachers’ talk and other linguistically-supportive behaviors of teachers ([Huttenlocher et al., 2002](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0145)). Second, prior research linking data-providing features of both teachers’ and parents’ talk to children’s language growth has focused on children who were younger than those in the present study; for instance, [Huttenlocher et al. (2002)](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0145) showed a significant, positive correlation between teachers’ syntactic complexity and children’s language growth for children who were three years of age. [Hoff’s (2003)](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0140) research linking mothers’ syntactic complexity to children’s vocabulary skills involved children who were two years of age. The children in the present study were older than those in the prior works, averaging 4 years of age at the study start. It may be that data-providing features of linguistic input become less salient as a source of language growth as children grow older, with opportunities to actively engage and participate in conversations with peers and adults becoming a more prominent mechanism for growth.

The present study has several important implications for practice and research, but before reviewing these we want to make clear the limitations of this study. First, there are dimensions of the linguistic environment that were not assessed in this study that may be especially significant, especially teachers’ use of questions ([Zucker, Justice, Piasta, & Kaderavek, 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0315)) and the conceptual focus of teachers’ talk ([Dickinson & Smith, 1994](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0045)). Thus, while our work shows that teachers’ communication-facilitating behaviors are an especially important dimension of the classroom linguistic environment, they may not be the only significant dimension. Future research needs to continue to investigate how best to represent the classroom linguistic environment and ensure that all relevant features are represented. Second, and relatedly, the assessments used to represent the linguistic environment of children’s classrooms did not transcend various contexts of discourse, with two of the assessments focused specifically on teacher-child proximal interactions during free-play. It is well-established that book reading is a particularly important context of the early education setting within which teachers can facilitate children’s language skills ([Dickinson & Smith, 1994](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0045)). Thus, future investigations of the dimensionality of the preschool classroom’s linguistic environment should explore how discourse contexts fit into such models. Third, the classrooms involved in this study served only children from disadvantaged backgrounds. These are a subset of children enrolled in center-based programming, and it is unknown whether the results in this study would generalize outward to include all preschool classrooms and an unselected sample of children. As preschool access continues to expand towards universal access, it is necessary to ensure that research findings focused on targeted-enrollment programs can appropriately be generalized. Fourth, with 49 classrooms in the sample, sample size was limited in level-2 of the latent growth model. However based on the simulation study of [Maas and Hox (2005)](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0190), a sample size of 50 is sufficient for producing unbiased parameter estimates and standard error for fixed effects. Finally, especially for grammar growth, the majority of individual variation lies at the child level, and the classroom-level linguistic environment variables had limited predictive power. Future research evaluating individual differences via the examination of child-specific language-learning environment features (e.g., how much individual child is exposed to teacher talk) is necessary to better understand young children’s language acquisition.

To conclude, we highlight several key implications of this work for practice. First, the importance of teachers’ linguistic responsivity in the preschool classroom, especially their use of communication-facilitating behaviors, should be emphasized. It appears that children’s engagement in extended conversations, a phenomenon explicitly facilitated by teachers’ behaviors, is extremely important to their language development, especially vocabulary ([Cabell et al., 2015](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0035)). To this end, we contend that pre- and post-professional development of teachers should explicitly support teachers to learn to use conversation-facilitating behaviors. However, with relatively little training, evidence points to teachers as being able to significantly increase their use of these behaviors ([Piasta et al., 2012](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0235)). Second, we also suggest that less attention be directed towards increasing the two dimensions of the classroom linguistic environment that are not linked to children’s language growth (the teacher talk and systems-level dimensions), when improving children’s language skills is a desired outcome. Specifically, it is extremely challenging to coach educators to use more syntactically complex or lexically diverse talk, as one’s linguistic skills are relatively intractable by adolescence ([Farkas & Beron, 2004](https://www.sciencedirect.com/science/article/pii/S0885200616301788" \l "bib0075)). Similarly, evidence shows that the systems-level general quality of preschool classrooms is also very difficult to change ([Early et al., 2017](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0065)), with intensive efforts resulting in only very small, incremental improvements. We interpret the present study as well as other prior works ([Cabell et al., 2015; Dickinson & Smith, 1994; Girolametto & Weitzman, 2002; Girolametto et al., 2003; Wasik & Bond, 2001; Zucker et al., 2010](https://www.sciencedirect.com/science/article/pii/S0885200616301788#bib0035)) to show that the most prominent lever for improving children’s language skills in the early education setting is to explicitly target the precise, proximal processes that lead to high-quality, extended conversations among teachers and children.

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**Appendix A.**

Equations of the two-level latent growth models are specified as below. Note that all equations are expressed in matrix forms in accordance with conventions of the SEM literature.

For child *i* nested within classroom *g*, let ***y****gi*‘ = [*ygi*1, *ygi*2, *ygi*3] represent the child’s outcomes (grammar or vocabulary scores) over three time points (year 1 fall, year 1 spring, and year 2 spring). At level 1, **y***gi* is modeled as

where μ*g*‘ = [μ*g*1, μ*g*2, μ*g*3] represents the random intercepts of the longitudinal measurements; Λ*W* is the 3 × 2 within-level factor loading matrix linking latent intercept and slope to the outcomes; η*gi*‘ = [η*gi-Intercept*, η*gi-Slope*] is the vector of within-level latent growth parameters; and ε*gi*‘ = [ε*gi*1, ε*gi*2, ε*gi*3] represent the within-level error. At level 2, the random intercept μ*g* is modeled as

where ΛΒ is a 3 × 2 between-level factor loading matrix; η*g*‘ = [η*g-Intercept*, η*g-Slope*] represents the between-level latent growth parameters; α is the mean vector that contains the fixed intercept and slope; ΓB is a 2 × 3 matrix describing the relationship between the three classroom-level predictors (teacher talk, system quality, and communication facilitation) and the latent growth parameters; ξ*g* is the 3 × 1vector containing the predictors; and ε*g*‘ = [ε*g*1, ε*g*2, ε*g*3] is the between-level error.

Given the unequal spacing between the three time points, and the complexities in early language development, we assume that the growth curve may be non-linear. Therefore, the factor loading matrices are defined as

where β3 represents the growth rate from time point 2 (year 1 spring) to time point 3 (year 2 spring) relative to the growth rate from time point 1 (year 1 fall) to time point 2.

Further, assuming normal distribution of latent growth parameters and error terms, we define

where Ψ is the 2 × 2 variance-covariance matrix of the latent growth parameters; and Θ is the 3 × 3 diagonal variance-covariance matrix of error terms.

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