Teacher-child Interactions and School Readiness among Dual Language Learning and Monolingual English-speaking Children in Early Childhood Settings

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Abstract

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Research has documented that school readiness is a critical factor that influences children's development over the life-course. However, there is limited research examining school readiness development, and the relationships between teacher-child interactions and school readiness among monolingual English-speaking and dual language learning children in preschool settings. The dissertation was conducted as part of a larger project in which I participated. It is comprised of three stand-alone studies that examined the development of preschool children's executive function, as well as how teacher-child interactions affected school readiness, defined as receptive language, literacy, math, and executive function development, among monolingual English-speaking and dual language learning children. Using two measures of executive function, the Peg Tapping task (PT; Diamond & Taylor, 1996) and the Dimensional Change Card Sort Task (DCCS; Zelazo, 2006), the first study examined the general trajectory and heterogeneity in the growth of executive function among children. Findings showed there was linear growth on children's executive function across monolingual English-speaking and

dual language learning children. Both populations varied significantly in their executive function skills at the beginning of the data collection period and in their growth rate of executive function over time. In addition, findings indicated that monolingual English-speaking children tended to have a higher initial level of executive function and a slower rate of growth in their executive function measured by the Peg Tapping task than dual language learning children. However, there was no significant difference between monolingual English-speaking children and dual language learning children in their growth of executive function measured by the DCCS during the data collection period. Utilizing the Classroom Assessment Scoring System Pre-K (CLASS Pre-K; Pianta et al., 2008), the second study tested the association between teacher-child interactions and children's receptive language, math, and literacy achievement. The results showed that CLASS Emotional Support predicted children's literacy and Math skills, Classroom Organization predicted children's receptive language and math skills, and Instructional Support predicted children's receptive language, literacy and math skills. In addition, monolingual English-speaking and dual language learning children tended to have higher math skills as the quality of Classroom Organization and Instructional Support increased. Furthermore, dual language learning children's math skills were higher compared to monolingual English-speaking children when they were in classrooms with higher Classroom Organization or Instructional Support. Finally, the third study examined threshold effects to understand whether associations between each CLASS domain were stronger at higher quality levels of teacher-child interactions, and whether the threshold effects differed between monolingual English-speaking and dual language learning children. Results from the piecewise regression showed that higher-quality-Classroom Organization was more strongly correlated with children's literacy and math skills compared to lower-quality classrooms. Similarly, the association between Instructional Support and math skills was stronger when in higher-quality classrooms. With regard to executive function, findings indicated that the relationship between Classroom Organization and DCCS, as well as Instructional Support and DCCS differed between monolingual English-speaking and dual language learning children. Findings from these three studies provide further evidence regarding the growth of executive function during the preschool period as well as the variability in children’s executive function development among monolingual English-speaking children and dual language learners. Study findings further highlight the importance of high quality teacher-child interactions in promoting children’s school readiness.

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DEDICATION

To my family and best friend

Introduction

Given the increased cultural and linguistic diversity in preschool classrooms, there is a need to examine school readiness development of children among monolingual English-speaking and dual language learning children. Dual language learners (DLLs) are children who are exposed to two languages either from birth or when they enter school and can function properly in each language based on different situational needs (Bihler et al., 2018; Carlson & Meltzoff, 2008; Downer et al., 2012; Edyburn et al., 2019; Langeloo, 2019). In the current dissertation, dual language learners (DLLs) are defined as children who primary speak a language other than English at home, including Mandarin, Vietnamese, Spanish, Somali and other languages (Downer et al., 2012). Several studies have pointed out that children with language and cultural disadvantages are at risk for poor school readiness as they progress through preschool (Bulotsky-Shearer et al., 2014). The increased presence of linguistically and culturally diverse dual language learners in early childhood settings, has led to a focus on more clearly examining the development of children in preschools. Therefore, the current dissertation targeted both monolingual English-speaking and dual language learning children to understand their school readiness, defined in these studies as receptive language, literacy, math, and executive function skills, and how teacher-child interactions affected their school readiness.

Executive function has been regarded as a critical skill that is associated with children's school readiness with rapid improvement in children's executive function occurring during preschool years (Montroy et al., 2016; Wanless et al., 2016). While many studies have examined the trajectories of executive function among monolingual English-speaking children, not much is known about the development of executive function among dual language learning children. Furthermore, several studies have pointed out that there are different trajectories between monolingual English-speaking and dual language learning children in the development of their executive function skills (Carlson & Meltzoff, 2008; Arizmendi et al., 2018). There is a critical need to more closely examine the developmental trajectory of executive function among monolingual and dual language learning children in early childhood settings. Such a focus will allow better support to be provided to enhance children's executive function development and growth. Hence, the first study focused on examining the development of preschool children's executive function.

While there is well established evidence indicating that executive function is crucial for school readiness, emerging studies have also pointed out the importance of teacher-child interactions in children's school readiness development (Carr et al., 2019; Hatfield et al., 2016). While there is emerging evidence indicating teacher-child interactions matter for children's school readiness, less is known about the specific aspects of how teacher-child interactions can effectively benefit dual language learners (White et al., 2020). Due to language and cultural disadvantages, dual language children may face more risks to their development (Bulotsky-Shearer et al., 2014). Bulotsky-Shearer et al., (2014) have noted that high-quality teacher-child interactions may serve as a protector to support children's strength in order to promote their school readiness. To date, although an extensive body of research has pointed out that high-quality teacher-child interactions may promote children's development (Burchinal et al., 2008; Goble & Pianta, 2017; Hu et al., 2019), more evidence is needed that takes into account the cultural and linguistic characteristics of dual language learners. Therefore, the second study sought to understand the relationship between teacher-child interactions and monolingual English and dual language children's school readiness, while the third study extended the study described in study two by testing whether the relationships between teacher-child interactions and children's school readiness were stronger when they were in classrooms with higher-quality levels of teacher-child interactions.

To address these issues regarding the school readiness of monolingual and dual language learning children in early childhood settings, the current dissertation included children participating in a larger project (Nores et al., 2018, 2019) in which I participated from 2016 to 2019. The project was launched by the city of Seattle's Department of Education and Early Learning (DEEL) in the 2015–16 school year and has been expanding every year since. The National Institute for Early Education Research at Rutgers University and Cultivate Learning, at the University of Washington have conducted the evaluation and data collection. The original project was a four-year project which evaluated the quality of classroom experiences and how children experience classroom quality in Seattle. The current dissertation utilized the data collected from 2017 to 2019 to understand children's development and school readiness during the preschool period.

The dissertation is comprised of three stand-alone studies. The first study focuses on the development of children's executive function, while the second and the third studies consider the role of teacher-child interactions on children's school readiness. Furthermore, the third study extends the second study by testing the threshold effects of teacher-child interactions on children's school readiness. A brief introduction to the three studies is as follows:

Study 1: The Development of Executive Function among Dual Language Learning and Monolingual English-Speaking Children in Early Childhood Settings

The purpose of the study was to understand the general trajectory of children's executive function, as well as whether there was heterogeneity among dual language learning and monolingual English-speaking children in their growth of executive function. In addition, the study examined whether monolingual English-speaking and dual language learning children demonstrated different developmental trajectories in their executive function development. This study utilized project data collected from 2017 to 2019 to understand children's executive function development overtime. And growth model using multilevel modeling was employed. Two executive function measures, the Peg Tapping (PT; Diamond & Taylor, 1996) and the Dimensional Change Card Sort Task (DCCS; Zelazo, 2006), were used in the study.

Study 2: Association between Teacher-child Interactions and Achievement among Monolingual English-speaking and Dual Language Learning Children

The study focused on understanding the association between teacher-child interactions and children's achievement among monolingual English-speaking and dual language learning children. The study used project data collected from Fall 2018 to Spring 2019 to examine how different domains of teacher-child interactions, as measured by the Classroom Assessment Scoring System Pre-K (CLASS Pre-K; Pianta et al., 2008), affected children's receptive language, literacy skills and math achievement. In addition, the study examined whether the associations between quality of teacher-child interactions and achievement differed among monolingual English speaking and dual language learning children. The study utilized two-level multilevel modeling to account for nesting of students within classrooms.

Study 3: Testing the Thresholds in the Association between Teacher-child Interactions and School Readiness among Monolingual English-Speaking and Dual Language Children

The study replicated previous studies examining threshold effects to test whether associations between each domain of the teacher-child interactions, Emotional Support, Classroom Organization, and Instructional Support (CLASS Pre-K; Pianta et al., 2008), and school readiness, defined as receptive language, literacy, math, and executive function skills, were stronger at higher quality levels of teacher-child interactions compared to lower quality levels of teacher-child interactions. Furthermore, the study extended previous studies by testing whether the threshold effects differed between monolingual English-speaking children and dual language learning children. Children participating in the project from Fall 2018 to Spring 2019 were included in the study. The mean scores for each domain of teacher-child interaction, as measured by CLASS, were used as cut-points and piecewise regression models using multilevel modeling were employed to estimate the threshold effects.

References

Arizmendi, G. D., Alt, M., Gray, S., Hogan, T. P., Green, S., & Cowan, N. (2018). Do Bilingual Children Have an Executive Function Advantage? Results From Inhibition, Shifting, and Updating Tasks. *Language, Speech, and Hearing Services in Schools*, *49*(3), 356–378. https://doi.org/10.1044/2018_LSHSS-17-0107

Bihler, L.-M., Agache, A., Schneller, K., Willard, J. A., & Leyendecker, B. (2018). Expressive Morphological Skills of Dual Language Learning and Monolingual German Children: Exploring Links to Duration of Preschool Attendance, Classroom Quality, and Classroom Composition. *Frontiers in Psychology*, *9*, 888. https://doi.org/10.3389/fpsyg.2018.00888

Bulotsky-Shearer, R. J., Bell, E. R., Carter, T. M., & Dietrich, S. L. (2014). Peer play interactions and learning for low-income preschool children: The moderating role of classroom quality. *Early Education and Development*, *25*(6), 815-840. https://doi.org/10.1080/10409289.2014.864214

Burchinal, M., Howes, C., Pianta, R., Bryant, D., Early, D., Clifford, R., & Barbarin, O. (2008). Predicting child outcomes at the end of kindergarten from the quality of pre-kindergarten teacher–child interactions and instruction. *Applied Development Science, 12*(3), 140-153. https://doi.org/10.1080/10888690802199418

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2), 282–298. https://doi.org/10.1111/j.1467-7687.2008.00675.x

Carr, R. C., Mokrova, I. L., Vernon-Feagans, L., & Burchinal, M. R. (2019). Cumulative classroom quality during pre-kindergarten and kindergarten and children's language, literacy, and mathematics skills. *Early Childhood Research Quarterly*, *47*, 218–228. https://doi.org/10.1016/j.ecresq.2018.12.010

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do". *Developmental Psychobiology*, *29*(4), 315–334. https://doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Downer, J. T., López, M. L., Grimm, K. J., Hamagami, A., Pianta, R. C., & Howes, C. (2012). Observations of teacher–child interactions in classrooms serving Latinos and dual language learners: Applicability of the Classroom Assessment Scoring System in diverse settings. *Early Childhood Research Quarterly*, *27*(1), 21-32. https://doi.org/10.1016/j.ecresq.2011.07.005

Edyburn, K. L., Quirk, M., & Oliva-Olson, C. (2019). Supporting Spanish–English Bilingual Language Development Among Latinx Dual Language Learners in Early Learning Settings. *Contemporary School Psychology*, *23*(1), 87–100. https://doi.org/10.1007/s40688-018-0209-7

Goble, P., & Pianta, R. C. (2017). Teacher–child interactions in free choice and teacher-directed activity settings: Prediction to school readiness. *Early Education and Development, 28*(8), 1035-1051. https://doi.org/10.1080/10409289.2017.1322449

Hatfield, B. E., Burchinal, M. R., Pianta, R. C., & Sideris, J. (2016). Thresholds in the association between quality of teacher–child interactions and preschool children's school readiness skills. *Early Childhood Research Quarterly*, *36*, 561–571. https://doi.org/10.1016/j.ecresq.2015.09.005

Hu, B. Y., Fan, X., Wu, Y., LoCasale-Crouch, J., & Song, Z. (2019). Contributions of Teacher–Child Interaction Quality to Chinese Children's Development in the Early Childhood Years. *Early Education and Development*, *30*(2), 159-177. https://doi.org/10.1080/10409289.2018.1544809

Langeloo, A., Lara, M. M., Deunk, M. I., Klitzing, N. F., & Strijbos, J.-W. (2019). A Systematic Review of Teacher–Child Interactions With Multilingual Young Children: *Review of Educational Research*. https://doi.org/10.3102/0034654319855619

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M., & Morrison, F. J. (2016). The development of self-regulation across early childhood. *Developmental Psychology*, *52*(11), 1744–1762. https://doi.org/10.1037/dev0000159

Nores, M., Barnett, W.S., Jung, K., Joseph, G. & Bachman, L. (2019). Year 4 report: Seattle Preschool Program evaluation. New Brunswick, NJ: National Institute for Early Education Research & Seattle, WA: Cultivate Learning

Nores, M., Barnett, W.S., Jung, K., Joseph, G., Bachman, L., & Soderberg, J.S. (2018). Year 3 report: Seattle Pre-k program evaluation. New Brunswick, NJ: National Institute for Early Education Research & Seattle, WA: Cultivate Learning.

Pianta, R. C., La Paro, K. M., & Hamre, B. K. (2008). *Classroom Assessment Scoring System^{TM} (CLASS^{TM}) Manual, Pre-K*. Baltimore, MD: Brookes Publishing.

Wanless, S. B., Kim, K. H., Zhang, C., Degol, J. L., Chen, J. L., & Chen, F. M. (2016). Trajectories of behavioral regulation for Taiwanese children from 3.5 to 6 years and relations to math and vocabulary outcomes. *Early Childhood Research Quarterly*, *34*, 104–114. https://doi.org/10.1016/j.ecresq.2015.10.001

White, L. J., Fernandez, V. A., & Greenfield, D. B. (2020). Assessing Classroom Quality for Latino Dual Language Learners in Head Start: DLL-Specific and General Teacher-Child Interaction Perspectives. *Early Education and Development*, 1-29. https://doi.org/10.1080/10409289.2019.1680785

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*(1), 297. https://doi.org/10.1038/nprot.2006.46

Study 1 - The Development of Executive Function among Dual Language Learning and Monolingual English-Speaking Children in Early Childhood Settings

Introduction

Executive function includes a set of control mechanisms linked to the prefrontal cortex of the brain that regulates individual cognition and action and is believed to be a core component of self-control ability (Garon et al., 2008; Miyake & Friedman, 2012). It involves the control and coordination of information that helps individuals prioritize their behaviors and use relevant information to make decisions (Montroy et al., 2016). Executive function provides children with the basis for regulating their own behaviors and thought to achieve their desired goals (Meuwissen & Englund, 2016). Stronger executive function skills allow children to engage effectively in the classroom by facilitating their memory of class rules and maintaining their focus in class, which helps them better navigate the structure of the learning environment (Schmitt et al., 2015). The development of executive function in early childhood has important implications for long-term outcomes as children enter other social and academic environments (Clark et al., 2013).

There is considerable evidence supporting the rapid improvement of executive function skills in children from three to six years of age (Anderson & Reidy, 2012; Carlson, 2005; Garon et al., 2008). However, despite increasing evidence that preschool is a critical period for the development of executive function, results of research investigating trajectories of children's executive function development are mixed. Some research indicates children demonstrated rapid and nonlinear gains during preschool (Montroy et al., 2016), while others suggest that children's executive function followed linear and quadratic trends (Wanless et al., 2016). In addition, little is known about whether children's development of executive function varies across individuals (Montroy et al., 2016). Specifying executive function trajectory, as well as the differences between children, is important for early intervention. Thus, the current study seeks to extend our understanding of children's executive function trajectories and the heterogeneity across children.

Aside from individual differences in executive function, findings from a number of studies have indicated that there are differences between dual language and monolingual language children in the development of their executive function skills (Carlson & Meltzoff, 2008; Arizmendi et al., 2018). Researchers have suggested that dual language learning children outperformed monolingual children in their executive functioning because they routinely practice controlling their attention to switch between two languages in their daily life (Bialystok, 1999). Dual language learners (DLLs) predominantly speak a language that differs from the language they learned at school and function properly in each language according to the situaltional needs (Bihler et al., 2018; Carlson & Meltzoff, 2008; Edyburn et al., 2019; Langeloo, 2019). These dual language experiences help dual language learners focus on relevant information and ignore irrelevant information, which is regarded as a critical skill of executive function.

If the experience of learning more than one language affects children's executive function performance, it would be noteworthy to investigate the developmental trajectory of executive function among dual language learning children and monolingual children. Whereas prior studies have mainly focused on the trajectory of monolingual children, examining trajectories among monolingual and dual language learning children, should permit a more thorough understanding of how bilingualism may affect children's development of executive function.

Defining executive function

Executive function refers to the higher-order cognitive processes that aid in the monitoring and controlling of thoughts and actions to help individuals attain goal-directed behaviors (Carlson, 2005; Meuwissen & Englund, 2016). It is a set of mental processes individuals need when they need to concentrate and pay attention to things on which they are working (Diamond, 2013). Executive function helps children to control, manage and monitor their behaviors to react adaptively to the environment (Montroy et al., 2016). Other constructs such as self-regulation and self-control also draw on the same underlying cognitive process (McClelland & Cameron, 2019).

There is general agreement that there are three core executive function components: working memory, inhibition and shifting (Diamond, 2013; Miyake & Friedman, 2012). Working memory refers to the ability to maintain and manipulate information over a short period of time (Lipsey et al., 2017). It helps children to actively maintain information over a brief period of time in a way that prevents distraction or interference of the information (Miyake & Friedman, 2012). Inhibition refers to suppression of irrelevant information or behaviors in order to complete a task (Miyake & Friedman, 2012). In the classroom, inhibition enables children to selectively attend and focus their attention on instruction and suppress their attention to other distractors. Shifting or switching includes the ability to flexibly switch between tasks or mental states as situations demand (Lipsey et al., 2017; Miyake & Friedman, 2012). These skills are crucial in early childhood because they help children control and maintain their attention, thereby facilitating their learning and engagement in the classroom.

The development of executive function in early childhood

Maturation of the attention system is believed to have important implication for the support of executive function. According to Garon et al., (2008), the development of two subsystems of attention, selective attention and focusing attention, as well as the interconnections between these subsystems help preschoolers to increasingly be able to control their thoughts and behaviors. Focusing attention enables preschoolers to ignore irrelevant information and focus on relevant information, whereas selective attention helps them sustain their attention for a longer period of time (Garon et al., 2008). The ability to focus on a task and ignore irrelevant information, and the ability to shift attentions are important when performing executive function tasks. These abilities continue to grow and progressively contribute to the child's ability to focus on executive function tasks.

Executive function components do not appear to develop in parallel but have different growth trajectories in early childhood. It is believed that working memory develops first, followed by inhibition, and shifting builds on these two components and develops later in early childhood (Diamond, 2013). Carlson (2005) examined children aged two to six years to determine the probability of successfully performing executive function tasks at each age. Though the ordering of the tasks varied according to children's age, children at younger ages passed more tasks that relied more on inhibition or working memory. Younger children passed fewer tasks that required shifting, indicating that shifting might come later than working memory and inhibition. Studies have suggested that shifting is the most complex executive function component that builds upon working memory and inhibition (Diamond, 2013; Garon et al., 2008).

Research examining children's executive function trajectory provides evidence that there is rapid growth in the preschool years (Carlson, 2005). Previous evidence suggests that inhibition shows striking improvement during the preschool period, whereas working memory and shifting tend to show gradual linear improvement (Best & Miller, 2010). Another study investigating children's executive function trajectory suggested that the general growth trajectory of executive function across early childhood was best represented by an exponential function (Montroy et al., 2016). In the study, researchers evaluated the trajectory of executive function during early childhood across three preschool samples with differing socioeconomic levels, and found children's executive function grew rapidly across all preschools, with only approximately 20% of children making minimal gains during preschool years. However, findings from a Taiwanese sample suggested that children tended to follow linear and quadratic trends on their executive function growth (Wanless et al., 2016).

Developmental trajectories have shown that between the ages of three and seven, there are individual differences regarding the beginning level of children's executive function skills, the time when rapid growth occurs and the rate of change (Montroy et al., 2016; Wiebe et al., 2012). Some children had higher initial levels of executive function and earlier gains, whereas other children started with lower executive function levels and gained slowly (Montroy et al., 2016). Wanless et al., (2016) found that there were two different executive function trajectories among children: increased steadily group, with children increasing steadily between 42 months and 72 months of age, and steady-then-increasing group, with children demonstrating few gains before 60 months and having a significant gain after five years old.

These developmental trends have led executive function development to typically be described in two main stages (Garon et al., 2008). One stage occurs before three years of age with the development of the attention system, while the other stage involves abrupt changes occurring during preschool. In general, growth of executive function in preschool aged children is rapid, with children taking only two to three years to go from minimal skills to mastery skills, and ultimately, children mastering the basic executive function skills needed to successfully perform executive function tasks (Montroy et al., 2016). While different components develop at different time points and have different growth trajectories, preschool aged children all gain at least some basic executive function skills needed to help them engage effectively in school. Though developing at a slower pace, these abilities continue to grow from simple capabilities to more complex integrated problem-solving skills through early adult years. Executive function may become more differentiated as children get older, allowing them to demonstrate more complex skills while completing the tasks which demand such skills (Karr et al., 2018).

Executive function development in monolingual children and dual language learning children

Cross sectional findings on whether there are differences in executive function between dual language learning children and monolingual language children are mixed. In Carlson and Meltzoff (2008)'s research, nine executive function tasks were used to measure kindergarten children's overall executive function. They found that dual language learning children, who were exposed to Spanish and English from birth, performed significantly better than monolingual children and children attending a language immersion school on the composite score of nine executive function tasks, after controlling for age, vocabulary and parents' education (Carlson & Meltzoff, 2008). In another study, Korean-English speaking children, who were enrolled in a Korean-English bilingual program in the United States for one school year, performed faster and more accurately on executive tasks as measure by the attention network test (ANT) compared to monolingual peers living in the United Sates and Korea (Yang et al., 2011). However, a recent study found that second-grade Spanish-English dual language learners did not score higher than their monolingual peers in any domain of executive function performance, including inhibition, updating and shifting (Arizmendi et al., 2018). Researchers have pointed out that the mixed results may be due to the variability of language exposure and use experienced by dual language learners (Crespo et al., 2019); Accordingly, some language exposure or use may have an influence on children's executive function development, while other kinds of language exposure or use may not.

Several longitudinal studies have been conducted to understand dual language influences (referred to as bilingual) and have found that bilingualism is advantageous to children's executive function development over time. In one longitudinal study, Tran et al. (2015) found that bilingual children tended to perform better than monolingual children on the Attention Network Test. Bilingual children demonstrated more accuracy and less response time on the tasks compared to monolingual children, with the bilingual advantage on overall accuracy persisting across time. In another study examining working memory, researchers found that while controlling for Dutch vocabulary and SES, bilingual children outperformed monolingual children at 6 years old but not at 5 years old (Blom et al, 2014). Another longitudinal study focusing on school-aged children (ages 8-12) have examined multiple executive function constructs among bilingual and monolingual children overtime. In the study, Park et al. (2018) found that monolingual and bilingual children demonstrated different patterns of development for inhibition but not for shifting. In addition, bilingual children demonstrated a steep improvement from year 1 to year 2, while there was a relatively stable growth for monolingual children on their inhibition. Results from these longitudinal studies suggested that monolingual and bilingual children differ in their growth of executive function. The effect of bilingualism on executive function may occur early in cognitive development and may persist over development from early childhood to later childhood in a continuous manner (Arizmendi et al., 2018; Carlson & Meltzoff, 2008; Yang et al., 2011).

Researchers supporting that dual language learning children outperform monolingual children have stated that executive function develops more rapidly in dual language learners because DLLs are advanced in their ability to control attention to conflicting situations (Carlson & Meltzoff, 2008). From a language learning perspective, language intrusions are prevented by holding relevant language in mind while inhibiting irrelevant language (Carlson & Meltzoff, 2008). In a dual language context, dual language learning children may be able to switch between languages, which is believed to trigger the highest demand of the cognitive control process that is associated with enhanced executive function (Crespo et al., 2019). Dual language learners routinely pay attention to abstract dimension of language, such as calling the same thing by two different languages, while monolingual children do not have to switch between languages (Bialystok, 1999, p.637). Dual language learners have more extensive practice of executive function in daily life (Carlson & Meltzoff, 2008). Dual language learners need to navigate two languages and thus learn to resist irrelevant information and distraction, while focusing on relevant information, therefore performing better on executive function tasks (Wiebe & Karbach, 2017). In summary, early childhood is a critical period for the development of executive function, and little is known about the trajectories of executive function among monolingual and dual language learning children. Questions about the challenges of learning dual languages on children’s executive function development are pressing and deserve further investigation.

Current study

Previous studies have indicated that there is possible heterogeneity in children's executive function trajectories (Montroy et al., 2016; Wiebe et al., 2012). However, most studies have been conducted with monolingual children who speak English as their primary language at home with few studies examining the executive function trajectory of dual language children. Given the lack of studies regarding the growth of executive function among monolingual children and dual language learning children, the current study is designed to provide researchers with a better understanding of the differences in executive function growth between dual language learning children and monolingual English-speaking children. The current study used two executive function measures, the Peg Tapping (PT; Diamond & Taylor, 1996) and the Dimensional Change Card Sort Task (DCCS; Zelazo, 2006), to assess children's executive function development. A growth model using multilevel modeling was utilized to understand children's initial levels and growth of executive function. The purpose of the study was to understand the general trajectory of children's executive function, as well as whether there was heterogeneity among children in their growth of executive function. Further, the study aimed to examine whether dual language learning children and monolingual English-speaking children demonstrated different developmental trajectories in their executive function. Answering these questions has implications for our understanding of executive function development among early childhood population, as well as practical aspects to consider when designing curriculum that benefits children's executive function development. Specifically, the present study proposed the following hypotheses,

Hypothesis 1: There is linear growth on children's executive function during preschool years.

Hypothesis 2: There is heterogeneity among children on their growth of executive function.

Hypothesis 3: Dual language learning children demonstrate higher initial level of executive function compared to monolingual English-speaking children.

Hypothesis 4: Dual language learning children show more accelerated growth in executive function development than monolingual English-speaking children.

Methods

Participants

The current study included children participating in a larger project (Nores et al., 2018, 2019) which evaluated the quality of classroom experiences and how children experience classroom quality from 2017 to 2019. Analyses were restricted to children who participated in both years of the study and had completed full battery of assessments: The Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV; Dunn & Dunn, 2007), Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III; Woodcock et al., 2001), Peg Tapping Test (PT; Diamond & Taylor, 1996), and Dimensional Change Card Sort Task (DCCS; Zelazo, 2006). The final sample included 122 children enrolled in 30 classrooms in preschools or family childcare centers in a large urban area in the North Western part of the United States. During the first time of testing in Fall of 2017, children averaged 3.68 years of age (*SD* = 0.29) with 56% female and 44% male. Of the 122 children for whom information on race/ethnicity was available, 34% were Asian, 32% were Black or African-American, 14% were Hispanic or Latino, 11% were White, 7% reported having two or more races and 1% were Native Hawaiian or Other Pacific Islander. Based on parent/caregive report, among these children, 57% spoke English as their primary language at home, while 43% spoke languages, such as Chinese, Spanish, Vietnamese or other languages as their primary language at home. Annual household income was reported by 101 families with 18% reporting household incomes lower than $25,000, 31% between $25,000 and

$50,000, 23% between $50,000 and $75,000, 5% between $75,000 and $100,000 and 4% above $100,000.

Procedure

Data used in the current study were collected from 2017 to 2019 with children being assessed during four times from Fall of 2017 to Spring of 2019. For the first two times, children were first assessed in Fall 2017 and assessed again at the end of the school year in Spring 2018. Similarly, for the third and fourth times, children were assessed in Fall 2018 and assessed again in Spring 2019. Children were assessed with a minimum of six months between assessments. Child measures were administered in direct, one-on-one interaction with a trained data collector. All data collectors received a two-day training on the measures and were given several days to practice. Data collectors were observed completing each measure by the Assessor Lead to test for reliability on assessments before starting data collection. Consent forms were distributed to parents or guardians before the data collection to recruit children to participate in the study. For children participating in the current study, children were asked to consent to participate prior to the administration of assessment. All assessments were conducted in English in a quiet place in the school or classroom. For children with a language other than English, an interpreter who spoke child's primary language, obtained informed consent.

Measures

The purpose of this study was to examine executive function development among monolingual English and dual language learning children. Two measures, Peg Tapping and DCCS, were utilized to measure children's executive function development.

Peg Tapping Test (PT). The Peg Tapping Test (PT; Diamond & Taylor, 1996) was used to measure children's executive function in the area of inhibition. Administration requires children to tap once when the assessor taps twice and tap twice when the assessor taps once. In order to respond correctly, the test requires children to remember the rules and inhibit their tendency to mimic the assessor's pencil taps. A total of sixteen trials are conducted with 8 one-tap and 8 two-tap trials in random sequence. Children received a score of 1 if they correctly respond to each trial and 0 if they respond incorrectly. The final score for the Peg Tapping Test is a sum of all the 16 items that comprise the test. To ensure that children understand the task, prior to beginning the actual assessment, two training tests are administered to children. Children need to correctly respond to two consecutive trials in order to continue to the formal assessment, otherwise, the assessment is abandoned and the child receives a -1 score for the assessment. The Peg Tapping Test has been shown to have good reliabilities of .87-.88 (Lipsey et al., 2017) and moderate construct validity with other teacher ratings of executive function r =.42 (Lipsey et al., 2017) and executive function tasks, r =.42 (Head-Toes-Knees-Shoulders task, HTKS) (Fuhs et al., 2015).

Dimensional Change Card Sort Task (DCCS). The Dimensional Change Card Sort Task (DCCS; Zelazo, 2006) was used to measure children's overall executive function, including working memory, inhibition and attention shifting. In this test, children were asked to sort cards based on different shapes and colors. There are a total of 24 test items across the tasks, with 6 items for the first two subtests and 12 for the last subtest. During the first subtest, children are asked to sort the cards based on different colors (e.g., red/blue rabbit to the red/blue box). If children respond correctly to five or more items, they are given the second subtask with 6 additional items, asking them to sort the cards based on different shapes (e.g., boat/rabbit to the boat/rabbit box). Similarly, if children respond correctly to five or more items on the second subtest, children are given the last subtask, with 12 addition items with combined rules. During the last subtest, children are asked to sort cards based on the color rule if there is a border on the card, otherwise, they need to sort the cards based on the shape rule if there is no border on the card. Children receive a score of 1 if they sort the card correctly and 0 if they sort incorrectly. Scores range from 0 to 24 with higher scores indicating more advanced levels of executive function. The DCCS has been shown to have good Cronbach alphas from .90 to .93. and test-retest reliability r = .63. (McClelland et al., 2014).

Missing data

There were no missing data in chidren's demographic information including child age, primary language, race, and gender. However, there were missing data to varying degrees for each time and variable (Table 2). The most missing data occurred in time 4 in Spring 2019. Beginning in fall 2017, 122 preschoolers were included in the study. For Peg Tapping, the missingness for each time were 2% in time 1 (N = 2), 3% in time 2 (N = 4), 12% in time 3 (N = 15) and 16% in time 4 (N = 20). For DCCS, the missingness for each time were 3% in time 1 and time 2 (N = 4), 13% in time 3 (N = 16) and 16% in time 4 (N = 20). The missing data were due to child absence or child being unable to pass the training items, causing the assessment to be aborted.

Analysis plan

Descriptive statistics and correlations between children's executive function across the four times were examined. The growth curve analysis using multilevel modeling was utilized to test the research questions. One of the advantages of multilevel modeling is that it can use the available data from an incomplete sample without reducing the sample size as do other approaches for modeling longitudinal data, nor does it require missing data methods (Finch et al., 2019). In addition, growth modeling allows us to estimate the form of repeated measurements (Level 1) nested within children (Level 2). The model provides information about the average value of children's executive function and the growth of their executive function skills over time. The current study therefore used multilevel modeling to describe the general trajectory of children's executive function development.

Children in the current study were assessed four times at equally spaced intervals, with a minimum of six months and a maximum of seven months between assessments. Accordingly, there were around 186 days between Time 1 and Time 2, 183 days between Time 2 and Time 3 and 182 days between Time 3 and Time 4 across each time point. The Time was coded as 0, 1, 2, 3 to represent the data collection period from Time 1 to Time 4. Children's gender was dummy coded with 0 representing males and 1 represents females. Similarly, children's language was coded into dichotomous variables, with monolingual English-speaking children coded 1 and dual language learning children coded 0.

An unconditional model (Model 0), with intercept only was fitted first to examine the variance in executive function that is explained by individuals (children). To answer the first two research questions which focus on the general trajectory of children's executive function and the heterogeneity among children, a random intercept and random slope model (Model 1), with gender as covariate, was tested. Specifically, the following model, separately for Peg Tapping and DCCS was tested:

Level 1: $EF_{ti} = \pi_{0i} + \pi_{1i} (Time_{ti}) + e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + \beta_{01} (Female_i) + r_{0i}$

$\pi_{1i} = \beta_{10} + \beta_{11} (Female_i) + r_{1i}$

where EF_{ti} is the executive function score for child *i* at time *t*. π_{0i} represents child *i*'s executive function level in the beginning of the data collection period where $Time_{ti}$ is 0; π_{1i} is the growth rate for child i during the data collection period and reflects child *i*'s predicted rate of growth on the executive function. Children's gender was entered into the model as the control variables at level 2. r_{0i} and r_{1i} are the random effect for a child's initial status and slope, which allows the growth to vary across children.

Finally, to answer the third and fourth research questions about whether dual language learning children and monolingual English-speaking children demonstrate different developmental trajectories on their executive function, an interaction model which included the interaction of time and children's language status was added (Model 2). Specifically, the following equation was tested for our analysis:

Level 1: $EF_{ti} = \pi_{0i} + \pi_{1i} (Time_{ti}) + e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + \beta_{01} (Language\ Status_i) + \beta_{02} (Female_i) + r_{0i}$

$\pi_{1i} = \beta_{10} + \beta_{11} (Language\ Status_i) + \beta_{12} (Female_i) + r_{1i}$

where EF_{ti} is the executive function score for child *i* at time *t*. π_{0i} represents a child *i*'s executive function level in the beginning of the data collection period where Time_{ti} is 0; π_{1i} is the growth rate for child i during the data collection period and reflects child *i*'s predicted rate of growth on the executive function. Both π_{0i} and π_{1i} are allowed to vary at level 2 as a function of children's language status. r_{0i} and r_{1i} are the random effect for a child's initial status and slope, which allow the growth to vary across children.

In addition, to understand children's executive function trajectory, both linear and quadratic models, with interaction between children's language status and time, were fitted to examine the trajectories of children's executive function, and the difference between monolingual English-speaking children and dual language learning children on their executive function growth. The best model fit was determined based on AIC, BIC, and log likelihood indices as shown in Table 4.

Results

Descriptive statistics of executive function

On average, children demonstrated growth in executive function as measured by Peg Tapping and DCCS. As shown in Table 1, both monolingual English-speaking children and dual language learning children demonstrated gains in executive function from Fall 2017 to Spring 2019. Individual trajectories for the complete sample on Peg Tapping and DCCS across four time points are presented in Figure 1 and Figure 2. For dual language learning and monolingual English-speaking children, there were individual differences on their initial status and growth rate. A smooth line was added to depict the overall pattern of the growth as shown in the black line. Table 3 shows the zero order correlations of the variables, there were positive correlations on Peg Tapping and DCCS between each time point. In addition, there were positive correlations between Peg Tapping and DCCS.

Figure 1

Children's Peg Tapping Score Trajectories

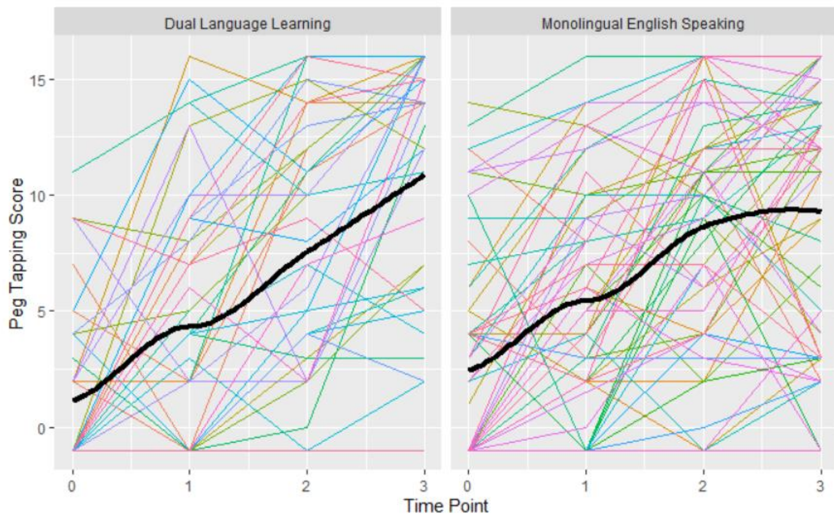


Figure 2

Children's Peg Tapping Score Trajectories

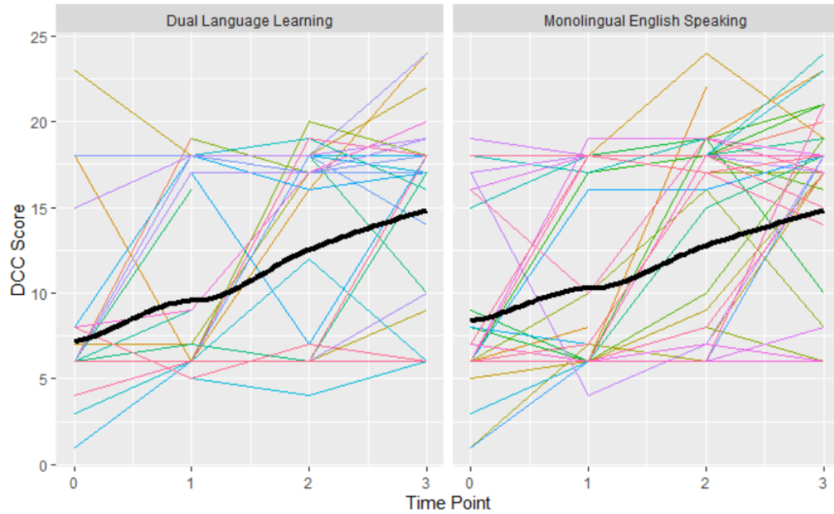


Table 1

Descriptive Statistics for Demographic Variables and Executive Function Measures

Demographics	Full sample (*N* = 122)			English-Speaking (*N* = 69)			Dual-Language (*N* = 53)		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Age (in years)	3.68	0.29	3.17-4.17	3.69	0.29	3.17-4.17	3.65	0.29	3.17-4.08
Gender (% male)	0.44			0.46			0.42		
Peg Tapping									
Fall 2017	1.86	4.10	-1-14	2.44	4.49	-1-14	1.12	3.43	-1-11
Spring 2018	4.96	4.97	-1-16	5.44	4.90	-1-16	4.32	5.03	-1-16
Fall 2018	8.19	5.54	-1-16	8.63	5.44	-1-16	7.54	5.68	-1-16
Spring 2019	9.94	5.74	-1-16	9.28	5.79	-1-16	10.88	5.58	-1-16
DCCS									
Fall 2017	7.79	4.49	1-23	8.37	4.76	1-19	7.04	4.03	1-23
Spring 2018	9.95	5.52	3-19	10.26	5.65	3-19	9.54	5.37	5-19
Fall 2018	12.66	5.92	4-14	12.76	5.99	6-24	12.52	5.87	4-20
Spring 2019	14.81	5.73	3-24	14.80	5.84	3-24	14.84	5.65	6-24

Note. DCCS = Dimensional Change Card Sort Task

Table 2

Frequency and Percent of Complete Data for Executive Function at Each Time Point

Variable	Time	Complete data	%
Peg tapping	0	120	98.36%
	1	118	96.72%
	2	107	87.70%
	3	102	83.61%
DCCS	0	118	96.72%
	1	118	96.72%
	2	106	86.89%
	3	102	83.61%

Note. DCCS = Dimensional Change Card Sort

Table 3

Zero-Order Correlation between Variables for Complete Data

	1	2	3	4	5	6	7	8	9
1. Chronological Age	1								
2. Peg tapping T1	0.11	1							
3. Peg tapping T2	0.16	0.47 ***	1						
4. Peg tapping T3	0.14	0.44 ***	0.62 ***	1					
5. Peg tapping T4	0.11	0.34 ***	0.58 ***	0.62 ***	1				
6. DCCS T1	0.11	0.45 ***	0.33 ***	0.27 **	0.21 *	1			
7. DCCS T2	0.16	0.47 ***	0.37 ***	0.29 **	0.26 **	0.42 ***	1		
8. DCCS T3	0.10	0.42 ***	0.35 ***	0.41 ***	0.28 **	0.35 ***	0.64 ***	1	
9. DCCS T4	0.13	0.36 ***	0.29 ***	0.31 **	0.35 ***	0.35 ***	0.46 ***	0.6 ***	1

**p < .05; **p <.01; ***p < .001.*
Note. DCCS = Dimensional Change Card Sort Task

Development of executive function

Fit statistics for the models are reported in Table 4 For Peg Tapping, the AIC and BIC suggested that the changes in children's executive function was best described by the linear with interaction model. Similarly, for DCCS, the AIC and BIC suggested that the changes in children's executive function was best described by the linear with interaction model, which included a linear growth of children's executive function, as well as an interaction between children's language status and time on their linear relationships with executive function.

Accordingly, there is a linear relationship between time and children's executive function, measured by Peg Tapping and DCCS. The results of the linear growth model are presented in Table 5.

Table 4

Summary of Growth Model Fit Statistics

Model	AIC	BIC	-2 log likelihood
Peg Tapping			
Linear	2615.90	2648.90	2599.90
Linear with interaction	2614.10	2651.10	2596.10
Quadratic	2631.40	2660.20	2617.40
Quadratic with interaction	2626.40	2663.50	2608.40
DCCS			
Linear	2682.00	2714.00	2666.00
Linear with interaction	2683.30	2720.20	2665.30
Quadratic	2692.20	2721.00	2678.20
Quadratic with interaction	2695.30	2732.30	2677.30

Note. DCCS = Dimensional Change Card Sort Task

General trajectory of children's executive function

An empty model (Model 0 - PT) was fitted and 32% of the variance in Peg Tapping was explained by children. The intercept value is estimated at 5.9, indicating that across the four times of the two-year data collection period, children had an average of 5.9 score on their Peg Tapping. As shown in Table 5, a linear model (Model 1 - PT) was fitted to understand the overall trajectory of children's executive function measured by Peg Tapping. Overall, children averaged 0.89 on their Peg Tapping at baseline. On average, children increased 2.65 score on their executive function measured by Peg Tapping every six months. Regarding the heterogeneity in children's executive function development, children varied significantly in their executive function measured by Peg Tapping in the beginning of the data collection period, with 2.82 score difference from the grand mean. Accordingly, a child whose Peg Tapping score is one point above the overall average is expected to have a score of 3.71(0.89+2.82) score in the beginning of the data collection period. Additionally, children varied significantly in their growth of executive function, with 1.08 difference from the grand mean. Accordingly, a child whose Peg Tapping growth is one point above the overall average is expected to grow at the rate of 3.73 (2.65+1.08) score every six months.

Similarly, for children's DCCS, an empty model (Model 0 - DCCS) was fitted and 34% of the variance in DCCS is explained by children. The intercept value is estimated at 10.99, indicating that across four times of the two-year data collection period, children had an average of 10.99 score on their DCCS. As shown in Table 5, a linear model (Model 1 - DCCS) was fitted to understand the overall trajectory of children's executive function measured by DCCS. Overall, children averaged 6.75 on their DCCS at baseline. On average, children increased 2.29 score in their executive function development measured by DCCS every six months. Regarding the heterogeneity in children's executive function development, children varied significantly in their executive function measured by DCCS in the beginning of the data collection period, with 3.08 score difference from the grand mean. Accordingly, a child whose DCCS score is one point above the overall average is expected to have a score of 9.83(6.75+3.08) score in the beginning of the data collection period. Additionally, children varied significantly in their growth of executive function, with 0.98 difference from the grand mean. Accordingly, a child whose DCCS growth is one point above the overall average is expected to grow at the rate of 3.28 (2.29+0.99) score every six months.

Heterogeneity in executive function among English-speaking children and dual language learning children

To understand whether there were differences between monolingual English-speaking children and dual language learning children in their executive function development, a growth model with interaction between time and their language status was fitted. As shown in Table 5

(Model 2 - PT), children increased 3.06 scores on their executive function measured by Peg Tapping every six months, on average, holding all else constant. English speaking children were predicted to have 1.69 higher scores compared to dual language learning children on their Peg Tapping. In addition, English speaking children were predicted to have 0.7 fewer scores every six months compared to dual language learning children, all else constant. As shown in figure 3, monolingual English-speaking children tended to have a higher initial level of executive function measured by Peg Tapping than dual language learning children. However, dual language learning children tended to have a faster rate of growth on their executive function development during the data collection period compared to monolingual English-speaking children.

Similarly, a growth model with interaction between children's language status was fitted to understand whether there were differences between monolingual English-speaking children and dual language learning children on their executive function development measured by DCCS. As shown in Table 5 (Model 2 - DCCS), children increased 2.49 scores on their executive function measured by DCCS every six months, on average, holding all else constant. English speaking children were predicted to have 1.12 higher scores compared to dual language learning children on their DCCS; however, this was not significant ($\beta = 1.12$, $p > .5$). Also, there was no significant difference between monolingual English-speaking children and dual language learning children in their executive function development measured by DCCS ($\beta = - .33$, $p > .5$). That is, there was no significant difference between monolingual English-speaking children and dual language learning children on their growth of executive function measured by DCCS during the data collection period.

Table 5

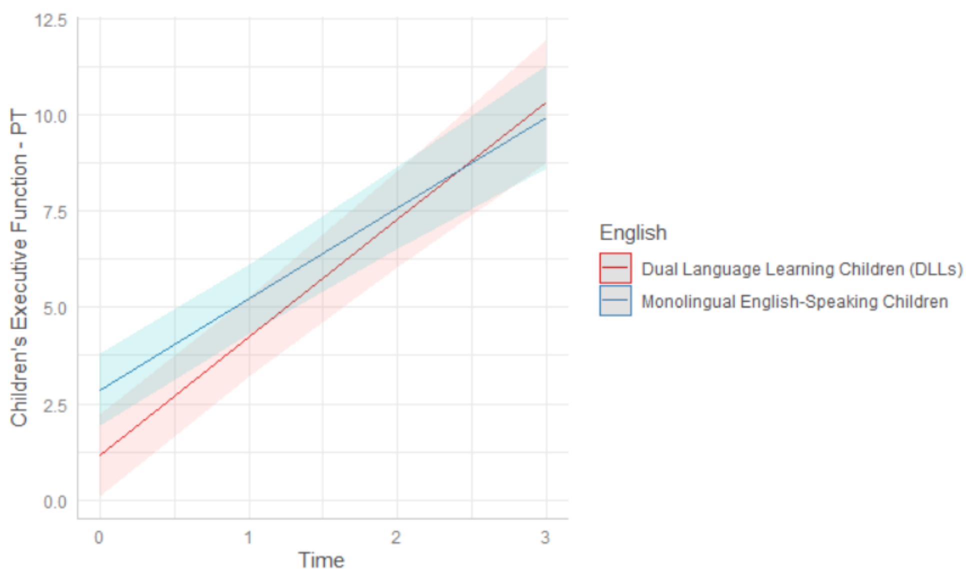
Growth Model Results for Children's Executive Function

	Model 0 - PT (Intercept only)			Model 1 - PT (Linear)			Model 2 - PT (Linear & Interaction)			Model 0 - DCCS (Intercept only)			Model 1 - DCCS (Linear)			Model 2 - DCCS (Linear & Interaction)		
Fixed Effects	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*
Mean initial status	5.90	(0.39)	***	0.89	(0.66)		0.62	(0.68)		10.99	(0.39)	***	6.75	(0.72)	***	6.60	(0.74)	***
Time				2.65	(0.18)	***	3.06	(0.27)	***				2.29	(0.19)	***	2.49	(0.29)	***
English				1.22	(0.69)		1.69	(0.72)	*				0.84	(0.74)		1.12	(0.81)	
Female				0.96	(0.68)		0.97	(0.68)					0.89	(0.74)		0.88	(0.74)	
Time*English							-0.70	(0.35)	*							-0.33	(0.38)	
Time Q																		
TimeQ*English																		
Random Effects	*Var*	*(SD)*		*Var*	*(SD)*		*Var*	*(SD)*		*Var*	*(SD)*		*Var*	*(SD)*		*Var*	*(SD)*	
Intercept																		
Students	11.47	(3.39)	*	7.93	(2.82)	*	7.81	(2.82)	*	12.39	(3.39)	*	9.49	(3.08)	*	9.44	(3.07)	*
Time				1.18	(1.08)	*	1.04	(1.18)	*				0.99	(0.99)	*	0.97	(0.98)	
Residual	23.89	(4.89)		10.83	(1.18)		10.87	(1.08)		23.78	(4.89)		13.72	(3.70)		13.72	(3.70)	
Model Information																		
Deviance (-2LL)	2847.00			2599.90			2596.10			2832.70			2666.00			2665.30		
AIC	2853.00			2615.90			2614.10			2838.70			2682.00			2683.30		
BIC	2865.30			2648.90			2651.10			2851.00			2714.90			2720.20		

Note: *N* = 122 students. DCCS = Dimensional Change Card Sort Task; PT = Peg Tapping Test
**p* < .05; ***p* <.01; ****p* < .001.

Figure 3

Interaction between Time and Language Status on Executive Function (PT)



Discussion

An extensive body of literature has pointed to the importance of executive function in preschool years as it is associated with short- and long-term school success. The primary goal of the current study was to understand the trajectory of children's executive function in early childhood and whether there was heterogeneity among early childhood learners in their executive function development. In addition, to extend previous studies examining the growth of executive function, the current study evaluated whether there was a difference between monolingual English-speaking children and dual language learning children in their executive function development. Two executive function measures, the Peg Tapping and DCCS, were used to understand children's executive function growth in the current study. The Peg Tapping test (PT; Diamond & Taylor, 1996) has been regarded as an inhibition task that requires withholding or restraining a response (Garon et al., 2008), while the Dimensional Change Card Sort Task (DCCS; Zelazo, 2006) has often been used to measure shifting or integrative executive function that involves the coordination of inhibition, working memory and shifting. Overall, findings from both executive function measures indicate that executive function rapidly increased during preschool years in this study. There is heterogeneity among children in their growth of executive function measured by the Peg Tapping and DCCS. In addition, there are differences between monolingual English-speaking children and dual language learning children in their executive function development as measured by the Peg Tapping.

The findings of this study indicated that there was linear growth on children's executive function during their preschool years across monolingual English-speaking and dual language learning children. This result is consistent with previous studies which have suggested that there is increased steadily growth of children's executive function between 42 and 72 months of age

(Wanless et al, 2011; Wanless et al., 2016). Additionally, children in this study varied significantly in their initial level of executive function measured by Peg Tapping and DCCS. These results are in line with previous findings indicating heterogeneity across children in their development (Montroy et al., 2016; Wanless et al., 2011). Accordingly, children demonstrated different levels of executive function across different measures and there was inter-individual variability in their executive function trajectory (Anderson & Reidy, 2012). Also, results for the present study found that children varied significantly in their growth rate of executive function measured by Peg Tapping and DCCS. While Peg Tapping captures children’s inhibition, the DCCS is believed to focus on children’s cognitive flexibility. The results of the study indicated that children in early childhood not only have different growth rates for inhibition skills, but also for cognitive flexibility. However, it is important to note that research in this area is limited and more longitudinal studies are needed to examine the trajectory of different executive function constructs over time. In general, this study concludes that children demonstrate steady growth of executive function during preschool years, with individual differences in their initial level and growth rate.

The study did not find that dual language learning children demonstrated higher initial levels of executive function. In contrast, the study found that monolingual English-speaking children demonstrated higher initial levels of executive function than dual language learners measured by the Peg Tapping test. This fits with previous findings indicating that there were no bilingual advantages in inhibition at initial levels (Wanless et al., 2011; Park et al., 2018). However, findings in the present study are inconsistent with previous studies which indicated that bilingual children performed better on executive function tasks than monolingual children (Carson & Meltzoff, 2008; Yang et al., 2011; Tran et al., 2015). This inconsistency in results could be because the children included in present study were assessed in English regardless of their proficiency in English, while children in other studies were assessed using non-verbal executive function tasks or in the preferred language of children. The Peg Tapping test, which requires children to understand the rules through assessors' directions in English, may be more difficult for dual language children to understand, resulting in lower executive function scores.

The results of the study reveal that dual language learning children demonstrated a faster rate of growth in executive function as measured by the Peg Tapping test compared to monolingual children. These findings are consistent with previous studies indicating that bilingual children outperformed monolingual children in their use of inhibition skills as time progressed (Park et al., 2018). As suggested by previous studies, dual language exposure may facilitate the growth of executive function (Crespo et al., 2019; Kuhn et al., 2016). Previous studies have found that changes in children's vocabularies were predictive of growth in executive function (Kuhn et al., 2016). Another study found that though there were no difference between monolingual and dual language children on their working memory at age 5, a bilingual advantage was evident when children reached six years of age (Blom et al., 2014). Further, studies have indicated dual language learners exhibit advanced inhibitory control because they are more likely to face environments where they need to deal with interfering responses from another language, thereby facilitating the development of inhibition (Crespo et al., 2019; Stocco et al., 2014). According to Stocco et al. (2014), dual language learners have superior capacities for inhibition because the top-down processing they use to process the first stimulus, which is mediated by the basal ganglia, tends to override their processing of the second stimulus. Therefore, dual language learners are more likely to focus on the intended stimulus and ignore the second stimulus while performing inhibition tasks. On the other hand, evidence of neuroimaging also supports the notion that exposure to dual languages is related to brain areas that are involved in executive function (Ramirez et al., 2017). Ramirez et al., (2017) has suggested that the simultaneous exposure to dual languages and the need to resolve language conflict in daily life may trigger the activity of bilateral prefrontal and orbitofrontal cortex, which will strengthen children's executive function of children.

Findings of the present study are inconsistent with previous studies indicating that dual language learning children improved their executive function at a slower rate compared to English-speaking children (Wanless et al., 2011). One reason for the discrepancy between our results and other studies may be due to the different racial or ethnicities of children included in other studies. The current study included children from diverse backgrounds with multiple languages, including Chinese, Spanish, Vietnamese, and other languages as their primary language. As stated, researchers have suggested that the variability of language use and exposure, as well as the characteristics of language may result in mixed results in the growth rate of children's executive function (Crespo et al., 2019). In addition, it remains unclear as to what specific aspects of dual language experience may have an impact on children's executive function performance (Crespo et al., 2019). Future studies are necessary to better understand children's executive function development across different languages. Specifically, more studies should evaluate how characteristics and use of different languages affect children's executive function development and what specific aspects of language lead to the development of children's executive function (Montroy et al., 2016). It is worthy to note that though dual language learning children in the current study did not demonstrate higher initial levels of executive function compared to monolingual English speaking children in the initial waves, a bilingual advantage in inhibition was evident with dual language children outperforming monolingual children as time went by.

Study findings did not indicate any significant difference between monolingual English-speaking and dual language learning children on their initial level and growth rate of executive function measured by the DCCS. These results are consistent with previous studies reporting no differences between monolingual and dual language children on the developmental rate of switching and shifting task (Park et al., 2018). One possible explanation for the nonsignificant findings on the DCCS may be that the coordination of multiple domains of executive function skills needed while performing the DCCS tasks tend to develop considerably later in life (Best & Miller, 2010). Shifting tasks, such as those measure by the DCCS, are considered to be more complex than inhibition or working memory tasks and requires multiple constructs of executive function (Park et al., 2018). Children need to be able to hold multiple rules in working memory and inhibit rules before they can successfully switch between different sets of rules (Anderson & Reidy, 2012; Garon et al., 2008). It is suggested children need to reach 5 years of age before they are able to sort things based on multiple rules (Anderson & Reidy, 2012). Although previous research indicates that dual language learning children were more skilled than monolingual children on DCCS (Bialystok, 1999), the DCCS, which is believed to capture children's shifting ability and overall executive function, may be relatively difficult for pre-schoolers and therefore not adequate enough to well capture children's overall executive function and detect the difference between monolingual English-speaking and dual language learning children . It is possible that children demonstrate different trajectories on different executive function measures that are designed to assess different aspects of executive function. Further investigation of how executive function develops across multiple executive function tasks is necessary to fully understand what attributes affect the development of children's executive function.

Limitations and future directions

There are several limitations of the current study. First, the study only utilized two measures to understand children's executive function development. While the Peg Tapping test was used to measure children's inhibition, the DCCS was used to measure children's coordination across different domains of executive function skills. Though these measures are reliable and have been widely used in the early childhood settings, they may not fully capture the nature of executive function development as executive function is a multidimensional concept (Montroy et al., 2016; Park et al., 2018). One challenge involved with measuring executive function is the task-impurity problem (Garon et al., 2008; Miyake & Friedman, 2012). Accordingly, it is difficult to measure a particular domain of executive function using a specific measure. Future study to understand the development of children's executive function should include multiple measures that capture the same executive function constructs, so that better support could be targeted to enhance children's executive function development to help them better engage in school.

Second, given the high percentage of missing data regarding children's socioeconomic status as reported by parents/caregivers (17.2%), the current study failed to control for children's socioeconomic status while examining the trajectory of executive function development. However, researchers have pointed out that family socioeconomic status, such as parental education, occupation, and household income, have been linked to children's cognitive development overtime (Pionitz et al., 2008; Montroy et al., 2016). It has beem found that parental education levels and socioeconomic status are positively correlated with children's executive function (Carlson et al., 2008). Socioeconomically disadvantaged children tend to score lower on their executive function compared to their peers (Blom et al., 2014). Future work is needed to control for these variables so that the trajectory of executive function across monolingual and dual language learning children could be accurately understood.

Finally, it is important to note that the effect of multilingualism on children's executive function may be different across different languages. It remains unclear as to what aspects of dual language experience and how exposure to different languages may have an impact on children's performance of executive function (Crespo et al., 2019). In addition, though it is expected that multilingual children may face more situations where they need to switch languages than bilingual children (Stocco et al., 2014), the effect of bilingualism and multilingualism on executive function is unknown. Dual language learning children participated in the current study were combined into the same group regardless of the languages they used and the number of languages they spoke. This may not fully capture the mechanism of how language affects children's executive function development. It is possible that there are overlaps between bilingualism and cultural influences on the development of children's executive function (Tran et al., 2015). It would be beneficial for future studies to take these factors into account to gain a thorough understanding of children's executive function across language groups.

References

Anderson, P. J., & Reidy, N. (2012). Assessing executive function in preschoolers. *Neuropsychology review*, *22*(4), 345-360. https://doi.org/10.1007/s11065-012-9220-3

Arizmendi, G. D., Alt, M., Gray, S., Hogan, T. P., Green, S., & Cowan, N. (2018). Do Bilingual Children Have an Executive Function Advantage? Results From Inhibition, Shifting, and Updating Tasks. *Language, Speech, and Hearing Services in Schools*, *49*(3), 356–378. https://doi.org/10.1044/2018_LSHSS-17-0107

Bialystok, E. (1999). Cognitive Complexity and Attentional Control in the Bilingual Mind. *Child Development*, *70*(3), 636–644. https://doi.org/10.1111/1467-8624.00046

Bihler, L.-M., Agache, A., Schneller, K., Willard, J. A., & Leyendecker, B. (2018). Expressive Morphological Skills of Dual Language Learning and Monolingual German Children: Exploring Links to Duration of Preschool Attendance, Classroom Quality, and Classroom Composition. *Frontiers in Psychology*, *9*, 888. https://doi.org/10.3389/fpsyg.2018.00888

Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish–Dutch children. *Journal of experimental child psychology*, *128*, 105-119. https://doi.org/10.1016/j.jecp.2014.06.007

Best, J. R., & Miller, P. H. (2010). A Developmental Perspective on Executive Function. *Child Development, 81*(6), 1641–1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, *28*(2), 595–616. https://doi.org/10.1207/s15326942dn2802_3

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2), 282–298. https://doi.org/10.1111/j.1467-7687.2008.00675.x

Clark, C. A. C., Sheffield, T. D., Chevalier, N., Nelson, J. M., Wiebe, S. A., & Espy, K. A. (2013). Charting early trajectories of executive control with the shape school. *Developmental Psychology*, *49*(8), 1481–1493. https://doi.org/10.1037/a0030578

Crespo, K., Gross, M., & Kaushanskaya, M. (2019). The effects of dual language exposure on executive function in Spanish–English bilingual children with different language abilities. *Journal of experimental child psychology*, *188*, 104663. https://doi.org/10.1016/j.jecp.2019.104663

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do". *Developmental Psychobiology*, *29*(4), 315–334. https://doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Dunn, L. M., & Dunn, D. M. (2007). PPVT-4: Peabody picture vocabulary test. Pearson Assessments.

Edyburn, K. L., Quirk, M., & Oliva-Olson, C. (2019). Supporting Spanish–English Bilingual Language Development Among Latinx Dual Language Learners in Early Learning Settings. *Contemporary School Psychology*, *23*(1), 87–100. https://doi.org/10.1007/s40688-018-0209-7

Finch, W. H., Bolin, J. E., & Kelley, K. (2019). Multilevel modeling using R. FL: Crc Press.

Ferjan Ramírez, N., Ramírez, R. R., Clarke, M., Taulu, S., & Kuhl, P. K. (2017). Speech discrimination in 11-month-old bilingual and monolingual infants: a magnetoencephalography study. *Developmental Science*, *20*(1), e12427. https://doi.org/10.1111/desc.12427

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessments and teacher ratings. *Journal of Educational Psychology*, *107*(1), 207–221. https://doi.org/10.1037/a0037366

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Honaker, J., King, G., & Blackwell, M. (2012). Amelia II: A program for missing data. *Journal of statistical software*, *45*(7), 1-47. http://artax.karlin.mff.cuni.cz/~hans/src/doc/r-cran-amelia/amelia.pdf

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. *Psychological Bulletin*, *144*(11), 1147–1185. https://doi.org/10.1037/bul0000160

Kuhn, L. J., Willoughby, M. T., Vernon-Feagans, L., Blair, C. B., & Family Life Project Key Investigators. (2016). The contribution of children's time-specific and longitudinal expressive language skills on developmental trajectories of executive function. *Journal of Experimental Child Psychology*, *148*, 20-34. https://doi.org/10.1016/j.jecp.2016.03.008

Langeloo, A., Mascareño Lara, M., Deunk, M. I., Klitzing, N. F., & Strijbos, J.-W. (2019). A Systematic Review of Teacher–Child Interactions with Multilingual Young Children. *Review of Educational Research*, *89*(4), 536–568. https://doi.org/10.3102/0034654319855619

Lipsey, M. W., Nesbitt, K. T., Farran, D. C., Dong, N., Fuhs, M. W., & Wilson, S. J. (2017). Learning-related cognitive self-regulation measures for prekindergarten children: A comparative evaluation of the educational relevance of selected measures. *Journal of Educational Psychology*, *109*(8), 1084–1102. https://doi.org/10.1037/edu0000203

McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00599

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children's early academic lives. *Early Childhood Research Quarterly*, *46*, 142–151. https://doi.org/10.1016/j.ecresq.2018.03.014

Meuwissen, A. S., & Englund, M. M. (2016). Executive function in at-risk children: Importance of father-figure support and mother parenting. *Journal of Applied Developmental Psychology*, *44*, 72–80. https://doi.org/10.1016/j.appdev.2016.04.002

Miyake, A., & Friedman, N. P. (2012). The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M., & Morrison, F. J. (2016). The development of self-regulation across early childhood. *Developmental Psychology*, *52*(11), 1744–1762. https://doi.org/10.1037/dev0000159

Nores, M., Barnett, W.S., Jung, K., Joseph, G., Bachman, L., & Soderberg, J.S. (2018). Year 3 report: Seattle Pre-k program evaluation. New Brunswick, NJ: National Institute for Early Education Research & Seattle, WA: Cultivate Learning.

Nores, M., Barnett, W.S., Jung, K., Joseph, G. & Bachman, L. (2019). Year 4 report: Seattle Preschool Program evaluation. New Brunswick, NJ: National Institute for Early Education Research & Seattle, WA: Cultivate Learning.

Park, J., Ellis Weismer, S., & Kaushanskaya, M. (2018). Changes in executive function over time in bilingual and monolingual school-aged children. *Developmental Psychology, 54*(10), 1842–1853. https://doi.org/10.1037/dev0000562

Ponitz, C. E. C., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly*, *23*(2), 141-158. https://doi.org/10.1016/j.ecresq.2007.01.004

Ferjan Ramírez, N., Ramírez, R. R., Clarke, M., Taulu, S., & Kuhl, P. K. (2017). Speech discrimination in 11-month-old bilingual and monolingual infants: a magnetoencephalography study. *Developmental Science*, *20*(1), e12427. https://doi.org/10.1111/desc.12427

Schmitt, S. A., McClelland, M. M., Tominey, S. L., & Acock, A. C. (2015). Strengthening school readiness for Head Start children: Evaluation of a self-regulation intervention.

Early Childhood Research Quarterly, *30*, 20–31. https://doi.org/10.1016/j.ecresq.2014.08.001

Stocco, A., Yamasaki, B., Natalenko, R., & Prat, C. S. (2014). Bilingual brain training: A neurobiological framework of how bilingual experience improves executive function. *International Journal of Bilingualism*, *18*(1), 67-92. https://doi.org/10.1177/1367006912456617

Tran, C. D., Arredondo, M. M., & Yoshida, H. (2015). Differential effects of bilingualism and culture on early attention: a longitudinal study in the US, Argentina, and Vietnam. *Frontiers in Psychology*, *6*, 795. https://doi.org/10.3389/fpsyg.2015.00795

Wanless, S. B., McClelland, M. M., Tominey, S. L., & Acock, A. C. (2011). The influence of demographic risk factors on children's behavioral regulation in prekindergarten and kindergarten. *Early Education & Development*, *22*(3), 461-488. https://doi.org/10.1080/10409289.2011.536132

Wanless, S. B., Kim, K. H., Zhang, C., Degol, J. L., Chen, J. L., & Chen, F. M. (2016). Trajectories of behavioral regulation for Taiwanese children from 3.5 to 6 years and relations to math and vocabulary outcomes. *Early Childhood Research Quarterly*, *34*, 104–114. https://doi.org/10.1016/j.ecresq.2015.10.001

Wiebe, S. A., Sheffield, T. D., & Andrews Espy, K. (2012). Separating the fish from the sharks: A longitudinal study of preschool response inhibition. *Child Development*, *83*(4), 1245–1261. https://doi.org/10.1111/j.1467-8624.2012.01765.x

Wiebe, S. A., & Karbach, J. (Eds.). (2017). Executive function: Development across the life span. Routledge.

Woodcock, R. W., McGrew, K. S., Mather, N., & Schrank, F. (2001). Woodcock-Johnson III NU tests of achievement. Rolling Meadows, IL: Riverside Publishing.

Yang, S., Yang, H., & Lust, B. (2011). Early childhood bilingualism leads to advances in executive attention: Dissociating culture and language. *Bilingualism: Language and Cognition*, *14*(3), 412–422. https://doi.org/10.1017/S1366728910000611

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*(1), 297. https://doi.org/10.1038/nprot.2006.46

Study 2 - Association between Teacher-child Interactions and Achievement among Monolingual English-speaking and Dual Language Learning Children

Introduction

An extensive body of research suggests that high quality classroom-level teacher-child interactions are positively associated with children's achievement, including literacy/language skills and mathematics achievement (Carr et al., 2019; Hamre et al., 2014; Hatfield et al., 2016). Additionally, children tend to have higher executive function along with higher language, literacy and mathematical skills when they experience high quality teacher-child interactions (Choi et al., 2016; Hatfield et al., 2016).

High quality teacher-child interactions are characterized by teachers' sensitivity and responsiveness to children's needs, teacher use of effective methods to manage students' behaviors, as well as instructional activities that promote students' higher-order thinking (Hamre et al., 2014). It is agreed that higher teacher-child interactions in a classroom may improve children's achievement in various domains by providing an environment where children feel supported and motivated (Hamre et al., 2014; Hatfield et al., 2016; Vernon-Feagan et al., 2019). When children experience supportive interactions, they exhibit have higher confidence levels and thus may be more motivated to explore the classroom environment, thereby promoting their achievement.

Teacher-child interactions in classrooms are interactive and influenced by reciprocal relationships among teachers and children (Day et al., 2015). Classrooms are becoming more diverse with not only monolingual English speakers but children with a primary language other than English, often referred to as dual language learners (Park et al., 2017). Dual language learners (DLLs) are children who are exposed to two languages either from birth or when they enroll in preschools (Bihler et al., 2018). These children most often hear and speak a language at home that differs from the language they hear and learn to speak at school, yet their culture and home language are rarely systematically combined into the classroom to help support their development (Edyburn et al., 2019; Langeloo et al., 2019). Furthermore, teacher-child interactions with DLL's may differ from interactions with monolingual English-speaking children's as DLL's may bring different sources of diversity and cultural backgrounds to the classroom (Langeloo et al., 2019). Notably, some studies have found that the quality of teacher-child interactions in the classroom can have a significant impact on dual language learning children's achievement (Bihler et al., 2018; Edyburn et al., 2019).

However, most studies examining association between teacher-child interactions and child outcomes have been focused on monolingual children, especially English-speaking children. Considerable uncertainty remains about the contribution of teacher-child interactions to the achievement of dual language children. Given the increase in cultural and language diversity within preschool settings, the present study aimed to gain a better understanding of the association between teach-child interactions and academic achievement among monolingual children and dual language learning children. Furthermore, the study evaluated whether the effect of teacher-child interactions on children's academic achievement differs between monolingual children and dual language learners. If there is indeed a difference in achievement levels, with monolingual children having higher levels than dual language children, understanding the difference can help teachers tailor their interactions to children with different language backgrounds, and therefore increase children's school achievement.

Measuring teacher-child interactions

To understand teacher-child interactions, researchers commonly use the Classroom Assessment Scoring System, which has three domains: Emotional Support, Classroom Organization and Instructional Support (CLASS; Pianta et al., 2008). The CLASS observation tool has been widely used in the early childhood settings to understand teacher-child interactions (Burchinal et al., 2012; Downer et al., 2012; Reily et al., 2019). Emotional Support is characterized as the emotional connection between the teacher and children. A teacher is aware, sensitive and responsive to children's needs, as well as being respectul and supportive to encourage children's autonomy and interests. A teacher in a high emotional support classroom is sensitive to children's needs and may provide supports to comfort and guide children in the face of distress, thereby supporting their achievement. Classroom Organization encompasses teacher management of children's behaviors and learning. When teachers set clear behavioral expectation, facilitate children's engagement through activities, and effectively maximize children's learning opportunities in school, children may feel less stressed and more actively engage in learning (Vandenbroucke et al., 2017). Instructional Support is characterized by teacher use of instructional discussions and learning activities to facilitate children's higher order thinking skills and language use. In a high instructional support classroom, teachers tend to ask questions that facilitate children's analysis and reasoning, as well as engage in sustained back and forth conversations with the children. It is believed that within the classroom context, the interactions between teachers and children can play a key role in children's learning and development in school (Vernon-Feagan et al., 2019).

Teacher-child interactions and dual language learning children

Dual language learners may involve interact with their teachers in a different manners as compared to monolingual children's interactions with their teachers. From a systematic review of Langeloo et al., (2019), they found teachers tended to use nonverbal communication techniques to interact with DLLs and maintain consistent classroom routines to help dual language children more fully engage in school activities. Reilly et al., (2019) also found that compared to monolingual English speakers, Spanish-speaking dual language learners benefited more from child-initiated activities with peers and adults where activities were apt to include more natural conversations. However, it is notable that though teachers adopted specific strategies in order to create more learning opportunities for dual language children, these children might receive unequal learning opportunities, such as different learning activities compared with monolingual children. Additionally, interactions between teachers and DLLs involves lower levels of linguistic complexity and vocabulary use (Langeloo et al., 2019).

Researchers have suggested that the difference in teacher-child interactions between monolingual and dual language learning learners could be due to expectation of teachers, as well as cultural differences between home and school (Langeloo et al., 2019). Tenenbaum and Ruck, (2007) examined whether teachers' expectations differed between minority students and European American students. They found that teachers tended to have more positive expectations of European American students and directed more positive and neutral speech to these students as compared with ethnic minority students, such as Asian American and Latino American (Tenenbaum & Ruck, 2007). Furthermore, Bossong and Keller (2018) interviewed mothers and teachers of different ethnic origins (German, Turkish and Russian) about their expectations regarding the importance of children's developmental goals. They found that teachers and parents reported differing expectations for children's development across different cultures, which may result in confusion for children regarding how to respond to classroom rules and expectations. These differing languages and cultural expectations between home and school may affect DLL's relationships with teachers, and in turn, possibly have a negative influence on their learning.

According to Tran et al. (2015), dual language children are defined not only by the language they speak, but also the culture to which they belong. Instead of learning multiple language or a new language in the classroom, dual language children often need to adjust to environments that involve two or more different cultures with different norms and expectations (Langeloo et al., 2019). Previous studies found that dual language learners benefited more when teachers created positive and respectful climates, and were sensitive to children's needs (Reilly et al., 2019). As children spend a great deal of time in the classroom, teacher-child interactions which encourage interaction and promote active student engagement become important for children's successful development. There is a critical need to understand the characteristics of interactions between teacher and dual language learners and how these interactive relationships may affect the achievement of dual language learners.

Teacher-child interactions and achievement among monolingual children

Studies have revealed that higher teacher-child interactions, characterized as teachers providing higher emotional and instructional support, as well as demonstrating higher behavioral management skills, can make a difference in monolingual children's achievement. Hamre et al., (2014) reported that instructional support predicted gains in children's language skills, as measured by the Peabody Picture Vocabulary Test and Woodcock-Johnson Picture Vocabulary Test. In the same study, they discovered that children, in classrooms where teachers were able to effectively redirect students' misbehavior, as well as engage students in productive transitions which maximized learning time, displayed gains in literacy skills (Hamre et al., 2014). Other study indicated that higher quality instructional interactions were positively linked to children's receptive language and expressive language and math, whereas emotional support was not related to children's language development skills (Mashburn et al., 2008). Similarly, Weiland et al. (2013) found classrooms with lower emotional support were negatively associated with children's receptive language skills. In a recent study, Vernon-Feagans et al. (2019) followed a representative sample of children from kindergarten to third grade who lived in low-wealth rural areas. They found that children who entered kindergarten with lower literacy skills benefited more from more years of high-quality teacher-child interactions compared to those who enter kindergarten with higher literacy skills, suggesting that high quality of teacher-child interactions can help to narrow the gap between children entered kindergarten with lower literacy skills and those who entered with higher literacy skills. Findings from these studies highlight the importance of the relationship high-quality teacher-child interactions and children's achievement

Teacher-child interactions and achievement among dual language learning children

Findings from previous studies examing whether teacher-child interactions are equally beneficial to dual language and monolingual children are mixed. According to (Downer et al., 2012), there are two competing perspective on the types of classroom experiences that may be beneficial to dual language learners. One viewpoint suggests that instruction tailored to a dual language learner's cultural and linguistic needs may be beneficial to these children, while another viewpoints suggests that less diverse classrooms can be equally beneficial to dual language learners and monolingual children (Downer et al., 2012).

As noted earlier, dual language learners are children who hear and speak a language other than English at home while hearing and speaking English in school (Downer et al., 2012). While these children can communicate in each language they speak, their proficiency in either language may not be as fluent as monolingual children and as a result they may engage in lower levels of language both at home and at school (Bihler et al., 2018; Carlson & Meltzoff, 2008). Despite the language gap between dual language learners and monolingual children, there is some evidence indicating that dual language children benefit more from high quality level teacher-child interactions (Bihler et al., 2018; Reilly et al., 2019). A study using a nationally representative sample of Head Start children found that compared to English speaking children, dual language children made more gains in receptive language when they were in classrooms with high quality emotional support (Reilly et al., 2019). In another recent study conducted in an urban Head Start program serving Spanish and English-speaking DLLs, White et al, (2020) found that classrooms with high Emotional Support and high Classroom Organization predicted dual language children's gains in executive function, which is critically important for children's development.

Studies have also revealed that Instructional Support may be particularly important for DLLs because these learners may have less exposure to English language at home compare to monolingual children (Reilly et al., 2019). A study conducted in Germany investigating whether teacher-child interactions were more important for dual language learners than for monolingual children, found that classrooms with higher Instructional Support were positively related to DLLs' language skills, while monolingual children's language skills were not related to higher levels of Instructional Support (Bihler et al., 2018). With English as the primary language of instruction in the United States, dual language learners face challenges as that they are not only developing conversational skills but also learning academic skills in their second language

(Reilly et al., 2019). A classroom with high quality instructional interactions may help to promote children's higher order thinking and language proficiency skills, therefore promoting their learning.

Conversely, other studies have found that children benefit from high quality of teacher-child interactions regardless of their language status. Downer et al., (2012) found that dual language learning children and Latino children both showed greater gains when they were in more emotionally supportive, better-organized, and higher instructional support classrooms compared to classrooms with lower teacher-child interactions. In another recent study, Reilly et al., (2019) found that regardless of children's language status, children tended to have higher language and literacy skills when classrooms were instructionally supportive and not overly managed.

Though children can benefit from a classroom where teachers provide high quality interactions, most studies regarding teacher-child interactions have been conducted with monolingual children; therefore, it is unclear whether the effects of teacher-child interactions on dual language learning children are similar to those of monolingual children. Given that there are increasing numbers of dual language children in early childhood settings (Park et al., 2017) and they tend to have lower language and literacy skills compare to monolingual children, understanding how dual language learners' preschool experiences may be different from their monolingual peers is critical. Examining which, if any, specific teacher-child interactions benefit these children becomes a pressing issue in the field of early childhood.

Current Study

The current study examined the associations between teacher-child interactions and children's achievement among monolingual English-speaking children and dual language learning children. In the current study, dual language learning children are characterized by children who speak a language other than English at home as their primary language and are exposed to English at school. Previous studies examining the relationships between teacher-child interactions and children's achievement have focused mostly on English-speaking children, with limited studies conducted to examine the relationship between teacher-child interactions and achievement of dual language learning children. The current study extends previous research by developing a deeper understanding of the association between teacher-child interactions and children's achievement, and whether the association is moderated by children's language status. Therefore, the current study had two primary goals. Using the Classroom Assessment Scoring System Pre-K (CLASS Pre-K; Pianta et al., 2008), the first goals was to examine how different domains of teacher-child interactions, Emotional Support, Classroom Organization, and Instructional Support, affected children's receptive language, literacy skills and math achievement. It was expected that children in classrooms where teacher-child interactions were high, would tend to have higher achievement. The second goal was to examine if the associations between teacher-child interactions and achievement differed between monolingual and dual language learning children. The study addressed two research questions: (1) What is the relationship between teacher-child interactions and children's achievement? (2) Does the associations between quality of teacher-child interactions and achievement differ among monolingual English speaking and dual language learning children? Specifically, the current study proposed the following hypotheses,

Hypothesis 1: Higher teacher-child interactions measured by CLASS are associated with higher levels of children's achievement, including receptive language skills, literacy skills, and math skills.

Hypothesis 2: The associations between teacher-child interactions and achievement are moderated by children's language status.

Methods

Participants

The data from the current study is drawn from a larger project which evaluated the quality of classroom experiences and how children experienced quality (Nores et al., 2019). Participants were 834 children (48% male and 52% female) ages between 3 to 5 years (*Mean* = 4.42 years old, *SD* = 0.5) in 82 classrooms across 59 preschools and family child-care centers in a large urban city in the northwestern part of the United States. Children were included in the study if they completed the full battery of assessments at pre and posttest. Children participating in the study were diverse in their background characteristics and based on the purpose of the study included monolingual English speaking children and dual language learners. Dual language learners were children who spoke a language other than English at home and were learning English in preschool. Overall, 72% of the children spoke English as their primary language at home, and the remaining 28% spoke a language other than English at home as reported by their parents/caregivers, including Mandarin, Somali, Cantonese, Spanish or other languages. Children were also racially/ethnically diverse, with parents/caregivers reporting 26.7% Black or African-American, 23% white, 18.8% Asian, 14.9% two or more races, 14.5% Hispanic or Latino, 0.6% Native Hawaiian or Other Pacific Islander and 0.5% American Indian or Alaskan Native. In terms of their household incomes, 17% reported household income lower than $25,000, 32% between $25,000 and $50,000, 23% between $50,000 and $75,000, 11% between $75,000 and $100,000 and 18% above $100,000.

Procedure

Data used in the current study were collected from Fall 2018 to Spring 2019. Individual child assessments, including Peg Tapping Test (PT), Dimensional Change Card Sort Task (DCCS), Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV) and two subtests of the Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III), - Letter Word Identification (LWID) and Applied Problem (AP), were conducted in Fall 2018 for pretest and again at the end of the school year in Spring 2019 for posttest. Children were assessed with a minimum of six months lapsing between the pre- and post-test. Prior to data collection, consent forms were distributed to families of children enrolled in the project. Child measures were administered in direct, one-on-one interactions with a trained data collector. All data collectors received a two-day training on the assessment and were given several days to practice before they went to the schools for data collection. For children participating in the current study, children were asked to consent to participate prior to the administration of assessments. All assessments were conducted in English in a quiet place in the school or classroom. For children with a language other than English, an interpreter who spoke the child's primary language, obtained informed consent form the child prior to the data collect begging the assessment.

To measure teacher-child interactions, classroom observations using the Classroom Assessment Scoring System Pre-K (CLASS Pre-K; Pianta et al., 2008), were conducted in the Winter of 2019 between the administration of pre- and post- individual child assessments. Full- and part-time data collectors were hired and received training. Prior to data collection, observer reliability was test. A trained observer rated the classrooms on each of the CLASS domain roughly every 30 minutes during an observation day, with 10 minutes break for scoring between each cycle. A total of four cycles were conducted within an observation day. The observation started from the time children arrived until the four cycles were done. A classroom's score for each of the nine dimensions was computed and three domain scores were calculated after the observation.

Measures

Children's achievement was measured at the child-level. Three measures, Peabody Picture Vocabulary Test, Woodcock-Johnson Psycho-Educational Battery - Letter-Word Identification subtest, Woodcock-Johnson Psycho-Educational Battery - Applied Problems subtest, were utilized to measure children's receptive language, literacy skills and math skills. Classroom observation was observed at the class-level using the Classroom Assessment Scoring System Pre-K to measure teacher-child interactions.

Child-level control variables

The current study controlled for children's gender, pre-test achievement score and executive function skills in Fall. These covariates have been shown to predict children's achievement in other studies (Montroy et al, 2016). Children's gender was dummy coded, children were coded 1 if they spoke English as their primary language and coded zero otherwise. Children's gender was dummy coded, with males coded 0 and zero otherwise. Children's executive function was measured by the Peg Tapping Test (PT; Diamond & Taylor, 1996) and the Dimensional Change Card Sort Task (DCCS; Zelazo, 2006). For the Peg Tapping Test, children receive -1 score if they fail to correctly response to the two consecutive trials, and the assessment will be abandoned. For formal assessment, 8 one-tap and 8 two-tap trials in random sequence, with a total of sixteen trials are conducted. Children receive a score of 1 for correctly response to each item and a score of 0 for incorrectly response to the item, with a sum of all the 16 items the comprise the final score. For the Dimensional Change Card Sort Task, children were asked to sort cards based on different shapes and colors. There are a total of 24 test items across the tasks, with 6 items for the first two subtests and 12 for the last subtest. Scores range from 0 to 24 where higher scores indicate higher levels of executive function.

Child-level measures

Receptive language

Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV). The Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV; Dunn & Dunn, 2007) was used to measure children's receptive language skills in English. The PPVT includes 228-items and can be used with population from 2.5 years to 90 years old. The PPVT-IV examines children's receptive vocabulary skills by asking them to point to the picture or say the number of the picture based on the data collector's instruction (e.g., Show me dog.). The test is standardized to a mean of 100 and a standard deviation of 15. For preschool children, the published split-half reliabilities range between .93 - .97, and test-retest reliabilities range between .91 - .94 (Dunn & Dunn, 2007).

Literacy skills and math skills

Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III). Two subtests of the Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III; Woodcock et al., 2001), Letter-Word Identification and Applied Problems were utilized in the present study. The Letter-Word Identification subtest subtest (LWID) was used to measure children's letter word knowledge and literacy skills. In this subtest, children are asked to identify letters, match words, and ultimately read words based on the instructions. The Applied Problems subtest (AP) was used to measure children's skills in analyzing and solving applied math problems. In this subtest, children are asked to solve increasingly more difficult problems involving number skills. The Woodcock-Johnson has been used in many large-scale preschool studies (e.g., Montroy et al, 2016). The test is standardized to a mean of 100 and a standard deviation of 15. The measure has shown medium reliability. The published reliabilities for individuals ages 5 to 19 range is .91 (Woodcock et al., 2001).

Classroom-level measures

Teacher-child interactions

Classroom Assessment Scoring System Pre-K (CLASS Pre-K). Teacher-child interactions were observed using the *Classroom Assessment Scoring System Pre-K (CLASS Pre-K*; Pianta et al., 2008). CLASS is an observational tool that assesses teacher-child interactions as a measure of classroom quality. Observations consist of four 20-minute cycles, with 10-minute coding periods between each cycle. Teacher-child interactions are measured through 10 dimensions in three domains: Emotional Support, Classroom Organization and Instructional Support. The Emotional Support domain includes four dimensions: Positive Climate, Negative Climate, Teacher Sensitivity, and Regard for Student Perspectives. The Classroom Organization domain includes three dimensions: Productivity, Behavior Management, and Instructional Learning Formats. The Instructional Support domain includes three dimensions: Concept Development, Quality of Feedback, and Language Modeling. Each dimension is rated on a seven-point Likert scale, where 1 indicates low quality and 7 indicates high quality. Three average scores were calculated based on three domains, with the three averaged domain scores then averaged for an overall quality score. Higher scores represent better Emotional Support, Classroom Organization and Instructional Support. According to the CLASS manual, a score of 1 or 2 indicates low quality, score of 3 to 5 indicate medium quality, and a score of 6 or 7 indicates high quality teacher-child interactions.

Prior to data collection, CLASS observers were trained by a CLASS certified trainer and met the Teachstone reliability certification requirements before conducting classroom observations. CLASS reliability agreement percentages for data collectors ranged between 92-98% (Nores et al., 2019). The CLASS has shown to have good internal consistency. The internal consistency of Emotional Support, Classroom Organization Instructional Support were 0.89, 0.79, 0.82, respectively (Downer et al., 2012).

Analysis plan

Data analyses were run using R x64 4.0.2 (R studio 1.3.1056). To answer the research questions, the study used a two-level multilevel modeling to account for nesting of students within classrooms. Each model had one CLASS domain entered and an interaction term with children's language status to see if associations with achievement differed by language status. Each CLASS domain was entered separately at a time to see how different aspects of teacher-child interactions were associated with children's academic achievement. In addition to language status, the model included children's achievement in Fall, age, gender (male as referent group) and executive function as covariates. In all analyses, predictors were grand-mean centered and standardized due to different scales across the measures. Children's language was dummy coded, monolingual-English children were coded 1 if they spoke English as their primary language at home and coded 0 for dual language learning children.

First, an intercept-only model was fitted to understand the variance accounted by classrooms, with seven multilevel models for each achievement. To answer the first research question regarding the relationship between teacher-child interactions and children's academic achievement, each domain of CLASS was entered to predict children's achievement in Spring. At level 1, achievement for student *i* in classroom *j* was regressed on children's pretest scores in

Fall, age, gender, and executive function scores. At level 2, each domain of the observed teacher-child interactions was entered. To answer the second research questions as to whether the associations between the quality of teacher-child interactions and academic achievement differed among monolingual and dual language children, a cross-level interaction between each domain of teacher-child interactions and children's language status was added to the model. The two-level model testing cross-level interactions is presented below.

Level 1 model (students):

$$Spring\ achievement_{ij} = \beta_{0j} + \beta_{1j}\ (Fall\ achievement_{ij}) + \beta_{2j}\ (Language\ Status_{ij}) + \beta_{3j}\ (Age_{ij}) + \beta_{4j}\ (Female_{ij}) + \beta_{5j}\ (Fall\ executive\ function_{ij}) + r_{ij}$$

Level 2 model (classroom):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\ (CLASS\ domain_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}\ (CLASS\ domain_j) + u_{2j}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50}$$

where i and j refer to students and classrooms. Spring achievement are the child-level outcomes in Spring, including receptive language, literacy skills and math skills; CLASS domains are different domains of class-level teacher-child interactions score; Fall achievement is child-level pretest outcomes in Fall; Language is child-level language status; Executive function represents child-level pretest scores on two executive function measures; Age and female (0 for male and 1 for female) are child-level characteristics.

Missing data

Overall, there was little missing data. Of the original of 844 children, there was no missing data for child age, language status, gender, and observed teacher-child interactions. For children's literacy skills, math skills and executive function, there were less than .04% of missing data (*Ns* = 2 – 4), with exception of receptive language (.08%, *N* = 7). Missing child data were mainly due to absence, child left the program or child was unable to complete the tasks. These children were excluded from the analyses. Therefore, the final analysis included 834 children with complete data on all variables.

Results

Descriptive statistics and preliminary analyses

Descriptive statistics for the study variables are presented in Table 1. Overall, children's scores on PPVT and WJ increased from Fall to Spring. For English-speaking children, PPVT (Fall PPVT, *M* = 101.47, *SD* = 17.85; Spring PPVT, *M* = 104.38, *SD* = 16.55), WJ- applied problem (Fall AP, *M* = 103.54, *SD* = 13.96; Spring WJ-AP, *M* = 104.48, *SD* = 12.99), whereas their WJ-letter word identification remains similar from Fall to Spring (Fall WJ-LWID, *M* = 102.02, *SD* = 13.89; Spring WJ-LWID, *M* = 101.86, *SD* = 14.39). For dual language learning children, PPVT (Fall PPVT, *M* = 84.1, *SD* = 16.70; Spring PPVT, *M* = 89.06, *SD* = 14.76), WJ-letter word identification (Fall WJ-LWID, *M* = 101.91, *SD* = 14.87; Spring WJ-LWID, *M* = 103.26, *SD* = 14.41), WJ- applied problem (Fall AP, *M* = 96.11, *SD* = 13.71; Spring WJ-AP, *M* = 100.56, *SD* = 11.89). For CLASS observation scores, as shown in Table 2, most classroom demonstrated high Emotional Support (*M* = 6.59, *SD* = 0.37) and Classroom Organization (*M* = 6.23, *SD* = 0.53), with relatively lower Instructional Support (*M* = 3.20, *SD* = 0.82).

Zero-order correlation of the variables are presented in Table 3. There were no significant correlations between children's PPVT in Fall and the three CLASS domain, while correlation between children's PPVT in Spring and CLASS Classroom Organization and Instructional Support were significant, $r = 0.11$, $p < 0.01$ and $r = 0.07$, $p < 0.05$, respectively; Similarly, as can be seen in Table 3, there were no significant correlations between children's WJ-LWID in Fall and CLASS domains, while correlation between children's WJ-LWID in Spring and CLASS Instructional Support were significant, $r = 0.09$, $p < 0.05$; Correlations between children's WJ-AP in Fall and CLASS Classroom Organization and Instructional Support were significant, $r = 0.12$, $p < 0.001$ and $r = 0.08$, $p < 0.05$, respectively; Finally, there were significant correlations between children's WJ-AP in Spring and three of the CLASS domains, Emotional Support ($r = 0.14$, $p < 0.001$), Classroom Organization ($r = 0.16$, $p < 0.001$), and Instructional Support ($r = 0.14$, $p < 0.001$).

Table 1

Descriptive Statistics for Demographic Variables, PPVT and WJ

Demographics	Full sample (*N* = 834)			English-Speaking (*N* = 600)			Dual-Language (*N* = 234)		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Age (in years)	4.42	0.5	3.16-5.25	4.44	0.49	3.17-5.25	4.4	0.51	3.17-5.25
Gender (% male)	48%			48%			50%		
Fall									
PPVT	96.61	19.19	20-153	101.47	17.85	20-153	84.1	16.7	35-126
WJ - Letter word	101.99	14.17	63-169	102.02	13.89	63-160	101.91	14.87	63-169
WJ - Applied problem	101.49	14.27	53-141	103.54	13.96	53-141	96.11	13.71	53-127
Spring									
PPVT	100.09	17.47	37-147	104.38	16.55	37-147	89.06	14.76	44-135
WJ - Letter word	102.26	14.4	57-175	101.86	14.39	57-175	103.26	14.41	69-161
WJ - Applied problem	103.38	12.81	49-146	104.48	12.99	49-146	100.56	11.89	49-132

Note. PPVT = Peabody Picture Vocabulary Test; WJ - Letter word = Woodcock-Johnson Psycho-Educational Battery - Letter-Word Identification subtest; WJ - applied problem = Woodcock-Johnson Psycho-Educational Battery - Applied Problems subtest

Table 2

Descriptive Statistics for CLASS

CLASS	Full sample (N = 834)		
	M	SD	Range
Emotional Support	6.59	0.37	5.15-7.00
Classroom Organization	6.23	0.53	4.13-7.00
Instructional Support	3.20	0.82	1.5-5.33

Table 3

Zero-order Correlation between Variables (N = 834)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Fall PPVT	1												
2. Fall WJ-LWID	0.26 ***	1											
3. Fall WJ-AP	0.69 ***	0.38 ***	1										
4. Fall Peg Tapping	0.49 ***	0.20 ***	0.53 ***	1									
5. Fall DCCS	0.47 ***	0.14 ***	0.49 ***	0.52 ***	1								
6. Spring PPVT	0.84 ***	0.18 ***	0.68 ***	0.48 ***	0.47 ***	1							
7. Spring WJ-LWID	0.23 ***	0.81 ***	0.35 ***	0.14 ***	0.11 **	0.21 ***	1						
8. Spring WJ-AP	0.58 ***	0.38 ***	0.73 ***	0.44 ***	0.42 ***	0.63 ***	0.43 ***	1					
9. Spring Peg Tapping	0.39 ***	0.14 ***	0.48 ***	0.58 ***	0.41 ***	0.46 ***	0.15 ***	0.45 ***	1				
10. Spring DCCS	0.47 ***	0.12 ***	0.51 ***	0.49 ***	0.57 ***	0.50 ***	0.13 ***	0.48 ***	0.44 ***	1			
11. CLASS ES	0.05	0.01	0.07	0.07	0.13 ***	0.07	0.05	0.14 ***	0.06	0.13 ***	1		
12. CLASS CO	0.05	0.02	0.12 ***	0.06	0.12 ***	0.11 **	0.06	0.16 ***	0.06	0.14 ***	0.71 ***	1	
13. CLASS IS	0.03	0.05	0.08 *	-0.01	0.06	0.07 *	0.09 **	0.14 ***	0.00	0.11 ***	0.38 ***	0.68 ***	1

$^*p$ < .05; $^{**}p$ <.01; $^{***}p$ < .001.

Note. PPVT = Peabody Picture Vocabulary Test; WJ - LWID= Woodcock-Johnson Psycho-Educational Battery - Letter-Word Identification subtest; WJ - AP = Woodcock-Johnson Psycho-Educational Battery - Applied Problems subtest; DCCS = Dimensional Change Card Sort Task; CLASS = Classroom Assessment Scoring System; CLASS-ES =Emotional Support domain of the CLASS; CLASS-CO = Classroom Organization domain of the CLASS; CLASS-IS = Instructional Support domain of the CLASS.

Multilevel models

As shown in Tables 4 to 6, first, an intercept-only model for each variable was conducted to estimate the amount of variability between and within classrooms and Intraclass correlations (ICC) were calculated (Model 0). Second, two-level hierarchical linear models were estimated to understand the associations between teacher-child interactions and children's achievement. Each domain of CLASS was entered individually to the model to understand the effect of CLASS domains on children's achievement, while controlling for their age, gender, executive function, and achievement in Fall (Model 1,3,5). Third, one CLASS domain and an interaction term with children's language status (English speaking =1 or dual language learning = 0) was included to see if the association between CLASS domains and children's achievement was moderated by children's language status (Model 2,4,6). The results of these analyses are presented below.

Teacher-child interactions and achievement

Receptive language. Results for the association between each CLASS domain and children's receptive language are presented in Table 4. Intraclass correlation (ICC) was calculated and classroom accounts for 16% of the variance in children's receptive language. As shown in Table 4, CLASS Emotional Support did not predict children's PPVT in Spring ($\beta = .02$, $p > .05$). On the other hand, CLASS Classroom Organization predicted children's PPVT in Spring ($\beta = .06$, $p < .01$), for every 1 standard deviation increase in Classroom Organization, there was an increase of .06 point on children's PPVT, holding all else constant. Similarly, CLASS Instructional Support predicted children's PPVT in Spring ($\beta = .05$, $p < .01$), for every 1 standard deviation increase in Instructional Support, there was an increase of .05 point on children's PPVT, holding all else constant. To understand whether the associations between teacher-child interactions and receptive language differed based on children's language status, an interaction term was added to the analysis. However, as shown in Table 4, none of the interactions between CLASS domains and children's receptive language were significant (βs = .01- .08, ps >.05).

Table 4

Multilevel Model Results for Children's Peabody Picture Vocabulary Test (PPVT) in Spring

	Model 0 (Intercept-Only)		Model 1 - ES (Main Effects)		Model 2 - ES (Interaction)		Model 3 - CO (Main Effects)		Model 4 - CO (Interaction)		Model 5 - IS (Main Effects)		Model 6 - IS (Interaction)	
Fixed Effects	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*
Intercept	-0.02		-0.11	*	-0.11	*	-0.11	**	-0.11	**	-0.11	*	-0.11	*
PPVT Pretest			0.74	***	0.74	***	0.74	***	0.74	***	0.74	***	0.74	***
English			0.14	**	0.15	***	0.15	***	0.15	***	0.15	**		**
Fall Age			-0.00		-0.01		-0.00	***	-0.00		-0.00		-0.01	
Female			-0.00		0.00		0.00		0.00		-0.00		0.00	
DCCS			0.08	***	0.08	***	0.07	**	0.08	***	0.08	***	0.08	***
Peg Tapping			0.07	**	0.07	**	0.07	**	0.07	**	0.07	**	0.07	***
CLASS-ES			0.02		-0.04									
CLASS-ES*English					0.08									
CLASS-CO							0.06	**	0.01					
CLASS-CO*English									0.07					
CLASS-IS											0.05	*	0.04	
CLASS-IS*English													0.01	
Random Effects	*Var*		*Var*		*Var*		*Var*		*Var*		*Var*		*Var*	
Intercept														
Classroom	0.16		0.02		0.02		0.01		0.01		0.02		0.02	
Residual	0.85		0.26		0.26		0.26		0.26		0.26		0.26	
Model Information														
Deviance (-2LL)	2312		1288		1285		1282		1279		1286		1285	
AIC	2318		1308		1307		1302		1301		1306		1307	
BIC	2332		1356		1359		1349		1353		1353		1359	

Note: N = 834 students within 82 classrooms. PPVT = Peabody Picture Vocabulary Test; DCCS = Dimensional Change Card Sort Task; CLASS = Classroom Assessment Scoring System; CLASS-ES =Emotional Support domain of the CLASS; CLASS-CO = Classroom Organization domain of the CLASS; CLASS-IS = Instructional Support domain of the CLASS.
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Literacy skills. Results for the association between each CLASS domain and children's literacy skills are presented in Table 5. Intraclass correlation (ICC) was calculated and classroom accounts for only 3% of the variance in children's literacy skills. As shown in Table 5, CLASS Classroom Organization did not predict children's literacy skills in Spring (β = .04, p > .05). However, CLASS Emotional Support predicted children's WJ-LWID in Spring (β = .05, p < .05), for every 1 standard deviation increase in Emotional Support, there was an increase of .05 points on children's WJ-LWID, holding all else constant. Similarly, CLASS Instructional Support predicted children's WJ-LWID in Spring (β = .05, p < .01), for every 1 standard deviation increase in Instructional Support, there was an increase of .05 point on children's WJ-LWID, holding all else constant. To understand whether the associations between teacher-child interactions and WJ-LWID differed based on children's language status, an interaction term was added to the analysis. However, as shown in Table 5, none of the interactions between CLASS domains and children's literacy skills were significant (β = .02, *ps* >.05).

Table 5

Multilevel Model Results for Children's Woodcock-Johnson - Letter Word Identification in Spring

	Model 0		Model 1 - ES		Model 2 - ES		Model 3 - CO		Model 4 - CO		Model 5 - IS		Model 6 - IS	
Fixed Effects	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*
Intercept	-0.00		0.06		0.06		0.06		0.06		0.06		0.06	
WJ-LWID Pretest			0.8	***	0.8	***	0.80	***	0.80	***	0.80	***	0.80	***
English			-0.11	*	-0.11	*	-0.10	*	-0.1	*	-0.10	*	-0.10	*
Fall Age			0.10	***	-0.10	***	-0.10	***	-0.10	***	-0.10	***	-0.10	***
Female			0.02		0.02		0.02		0.02		0.02		0.02	
DCCS			0.03		0.03		0.03		0.03		0.03		0.03	
Peg Tapping			0.01		0.01		0.02		0.01		0.02		0.02	
CLASS-ES			0.05	*	0.04									
CLASS-ES*English					0.02									
CLASS-CO							0.04		0.02					
CLASS-CO*English									0.02					
CLASS-IS											0.05	*	0.04	
CLASS-IS*English													0.02	
Random Effects	*Var*		*Var*		*Var*		*Var*		*Var*		*Var*		*Var*	
Intercept														
Classroom	0.03		0.02		0.02		0.07		0.02		0.02		0.02	
Residual	0.97		0.31		0.31		0.31		0.31		0.31		0.31	
Model Information														
Deviance (-2LL)	2363		1418		1418		1420		1420		1419		1419	
AIC	2369		1438		1440		1440		1442		1439		1441	
BIC	2383		1485		1492		1487		1494		1486		1493	

Note: *N* = 834 students within 82 classrooms. WJ-LWID = Woodcock-Johnson - Letter Word Identification; DCCS = Dimensional Change Card Sort Task; CLASS = Classroom Assessment Scoring System; CLASS-ES =Emotional Support domain of the CLASS; CLASS-CO = Classroom Organization domain of the CLASS; CLASS-IS = Instructional Support domain of the CLASS.
**p* < .05; ***p* <.01; ****p* < .001.

Math skills. Results for the association between each CLASS domain and children's math skills are presented in Table 6. Intraclass correlation (ICC) was calculated and classroom accounts for 8% of the variance in children's math skills. As shown in Table 6, each domain of CLASS predicted children's WJ-AP in Spring (βs = .08, *ps* < .01). For every 1 standard deviation increase in Emotional Support, Classroom Organization, or Instructional Support, there is an increase of .08 point on children's WJ-AP, holding all else constant. To understand whether the associations between teacher-child interactions and WJ-AP differ based on children's language status, an interaction term was added to the analysis. As shown in Table 6, there was significant interaction between CLASS Classroom Organization and children's language status on WJ-AP

(β = - .12, p < .05), as well as interaction between CLASS Instructional Support and children's language status on WJ-AP (β = - .11, p < .05).

Table 6

Multilevel Model Results for Children's Woodcock-Johnson - Applied Problem in Spring

	Model 0		Model 1 - ES		Model 2 - ES		Model 3 - CO		Model 4 - CO		Model 5 - IS		Model 6 - IS	
Fixed Effects	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*	*coeff (SE)*	*p*
Intercept	-0.01		0.08		0.08		0.07		0.07		0.07		0.07	
WJ-AP Pretest			0.62	***	0.62	***	0.61	***	0.62	***	0.61	***	0.62	***
English			-0.08		-0.08		-0.07		-0.07		-0.07		-0.07	
Fall Age			-0.20	***	-0.20	***	-0.20	***	-0.20	***	-0.20	***	-0.20	***
Female			-0.04		-0.04		-0.04		-0.04		-0.04		-0.04	
DCCS			0.11	***	0.11	***	0.11	***	0.11	***	0.12	***	0.11	***
Peg Tapping			0.13	***	0.13	***	0.14	***	0.14	***	0.14	***	0.13	***
CLASS-ES			0.08	**	0.09									
CLASS-ES*English					-0.01									
CLASS-CO							0.08	**	0.16	***				
CLASS-CO*English									-0.12	*				
CLASS-IS											0.08	**	0.15	***
CLASS-IS*English													-0.11	*
Random Effects	*Var*		*Var*		*Var*		*Var*		*Var*		*Var*		*Var*	
Intercept														
Classroom	0.09		0.02		0.02		0.02		0.02		0.02		0.02	
Residual	0.91		0.40		0.40		0.40		0.40		0.40		0.40	
Model Information														
Deviance (-2LL)	2346		1635		1635		1637		1632		1657		1632	
AIC	2352		1655		1657		1657		1654		1704		1654	
BIC	2366		1702		1709		1704		1706		1637		1706	

Note: N = 834 students within 82 classrooms. WJ-AP = Woodcock-Johnson - Applied Problem; DCCS = Dimensional Change Card Sort Task; CLASS = Classroom Assessment Scoring System; CLASS-ES =Emotional Support domain of the CLASS; CLASS-CO = Classroom Organization domain of the CLASS; CLASS-IS = Instructional Support domain of the CLASS.
*p < .05; **p <.01; ***p < .001.

To understand the nature of the association between CLASS-Classroom Organization and language status on children's WJ-AP, predicted values of children's WJ-AP in Spring were plotted by children's language status. As shown in Figure 1, for Classroom Organization, there was no significant difference between English speaking and dual language learning children on their math skills in Spring when they were in classroom with lower level Classroom Organization domain scores. However, as the quality of the Classroom Organization domain increased, English speaking children and dual language learning children tended to have higher math skills in Spring. In addition, dual language learning children's math skills were higher compared to monolingual English-speaking children when they were in classroom with higher Classroom Organization domain scores.

Similarly, there was no significant difference between English speaking and dual language learning children on their math skills in Spring when they were in classrooms with lower Instructional Support domain scores as shown in Figure 2. But as levels of Instructional Support increases, English-speaking children and dual language learning children tended to have higher math skills in Spring. Additionally, dual language learning children's math skills were higher compared to monolingual English-speaking children when they were in classrooms with higher Instructional Support.

Figure 1

Interaction between CLASS - Classroom Organization and Children's Language Status on Math Skills in Spring

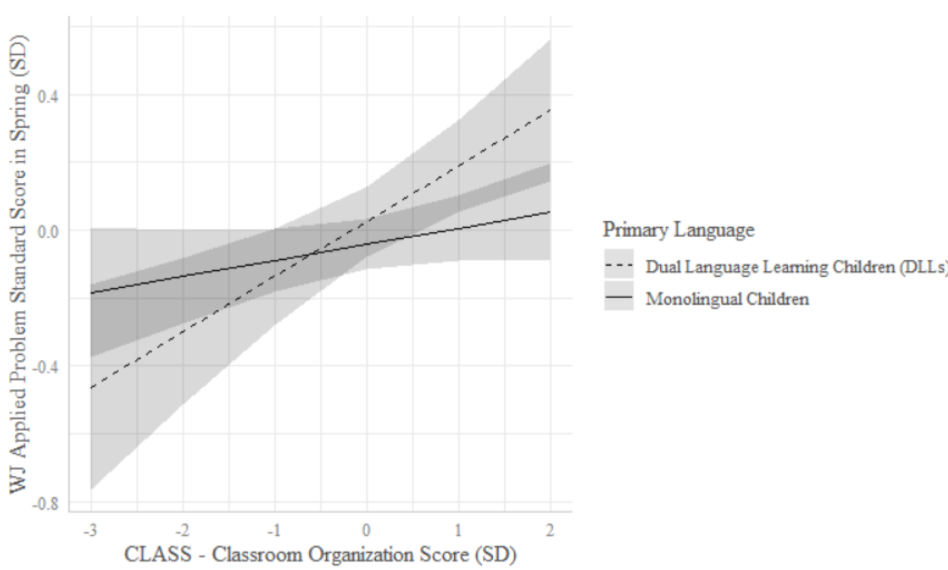
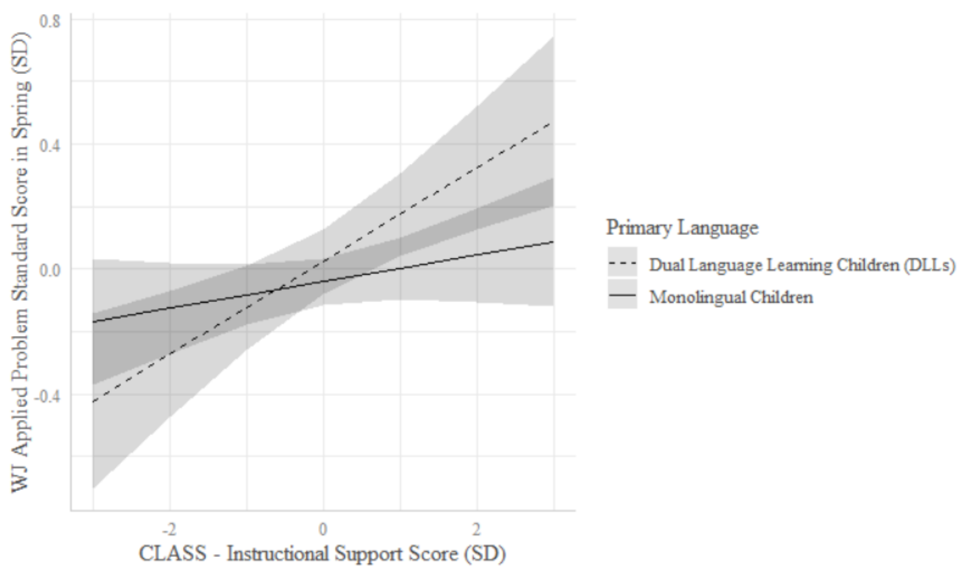


Figure 2

Interaction between CLASS - Instructional Support and Children's Language Status on Math Skills in Spring



Discussion

This study had two goals to gain a deeper understanding of the association between teacher-child interactions and children's achievement. The first goal examined how teacher-child interactions contributed to children's achievement, including receptive language skills, literacy skills, and math skills. The findings showed that Emotional Support predicted children's literacy skills and math skills. However, Emotional Support did not contribute to children's receptive language. In addition, Classroom Organization predicted children's receptive language and math skills but did not predict their literacy skills. Finally, Instructional Support consistently predicted receptive language, literacy, and math skills in the current study. The second goal was to explore differences in association between teacher-child interactions and achievement for monolingual English-speaking children versus dual language learning children. Results indicated that few significant differences were found for relationships between teacher-child interactions and achievement by children’s language status. However, as levels of Classroom Organization and Instructional Support increased, English speaking children and dual language learning children tended to have higher math skills on Spring assessment results. Further, dual language learning children tended to have higher math skills compared to monolingual English-speaking children when they were in classrooms with higher Classroom Organization and Instructional Support domain scores. The results of this study advance our understanding of the association between teacher-child interactions and achievement among monolingual English-speaking and dual language learning children.

Emotional support and achievement

In line with previous studies indicating that children in a more emotionally supportive classroom showed greater gains in literacy skills (Carr et al., 2019; Downer et al., 2012; Goble & Pianta, 2017), the current study found that children demonstrated better literacy skills when teachers were consistently responsive to students’ needs, and aware of students who needed extra support. In addition, the study also found that higher emotionally supportive classrooms were associated with higher math skills. In a classroom where teachers are approachable and sensitive to children’s needs, children may enjoy the supportive and positive environment, and can comfortably and freely engage in the classroom actively, thereby improving their learning. However, the current study did not find that Emotional Support contributed to children’s receptive language, which is similar to findings of previous studies indicating no relationship between Emotional Support and receptive language (Reilly et al., 2019). It is possible that although teachers provided an environment of warmth and safety that was beneficial to the children, teachers did not provide adequate interactions for children to improve their receptive language skills. Other researchers also pointed out that it is possible that once children’s basic needs of being supported and cared for are met, the contribution of Emotional Support to children's achievement becomes limited (Hu et al., 2019). However, it is important to note that though the current study did not find that Emotional Support predicted children's receptive language, this does not mean that engaging in emotionally supportive and responsive interactions with children in the classroom is not important (White et al., 2020). Reseachers examining the relationship between Emotional Support and children's achievement found that although Emotional Support was not associated concurrently with children's achievement in preschool, experiencing high Emotional Support in preschool may have a lasting effect on children's skills in kindergarten (Reilly et al., 2019).

Classroom organization and achievement

In line with previous study conducted in China (Hu et al., 2019), findings of the current study showed that higher Classroom Organization predicted children's receptive language. Classrooms with high Classroom Organization are characterized by teachers who effectively provide clear expectations to prevent misbehavior and efficiently organize and manage routines to maximize students' engagement in school (Pianta et al., 2008). This suggests that being in a classroom where teachers organize and manage instructional time and routines may provide children more opportunities to practice using language (Reily et al., 2019). Further, the present study found that Classroom Organization predicted children's math skills. This is consistent with previous studies indicating that children in better-organized classrooms made greater gains in math skills (Downer et al., 2012; Hu et al., 2019). Doing mathematics requires children to retrieve previous knowledge and switch their attention to concentrate on manipulating the numbers in problems. When a classroom is well-organized, good behavior management is established and children may appear to be more engaged in and focus on classroom work. This enables children to maintain their attention on information needed for mathematical problem solving and increase their flexibility while manipulating numbers (Fuhs et al., 2015; McClelland & Cameron, 2019). In addition, in a classroom with higher Classroom Organization, there are more variety of materials for children to explore and teachers may be more effectively in engaging students with a variety of modalities. These provide children with more opportunities to manipulate and explore materials, and therefore, maximize students' learning and benefit their math skills. However, the present study did not find that Classroom Organization contributed to children's literacy skills. It is possible that in a well-organized classroom, although teachers effectively manage children's behaviors and provide them with a variety of resources to explore, there are limited opportunities for children to practice literacy skills needed for reading and writing. These results are inconsistent with previous studies indicating that children in better-organized classrooms made greater gains in language skills (Bulotsky-Shearer et al., 2014; Carr et al., 2019; Downer et al., 2012; Hu et al., 2019). Further study is needed to better examine the association between Classroom Organization and children's language skills.

Instructional support and achievement

Though it is possible that low scores of Instructional Support may leave little room for predictive ability on children's achievement (White et al., 2020), Instructional Support emerged as an important factor in that it consistently predicted children's receptive language, literacy skills, and math skills in the current study. This is consistent with existing findings indicating that children in classrooms with higher Instructional Support classrooms made greater gains in receptive language (Carr et al., 2019; Hu et al., 2019), literacy skills (Carr et al., 2019; Downer et al., 2012;), as well as math skills (Burchinal et al., 2008; Downer et al., 2012). Results from studies conducted outside of the United States indicated similar results with children demonstrating better literacy skills and math skills when teachers consistently provided high-quality of Instructional Support (Hu et al., 2017). Several researchers have found that Instructional Support is particularly important for children's language development, indicating that more years of high quality of Instructional Support is positively correlated with children's achievement and effects would sustain even after children enter kindergarten (Carr et al., 2019; Burchinal et al., 2008). If teachers effectively support children through interactions rich in feedback and modeling, children may have more opportunities to practice using language and therefore enhance their language skills (Goble & Pianta, 2017). Furthermore, solving math problems require that children comprehend the text of the problem and identify the questions that need to be solved. As children's literacy and language skills improve, their abilities to understand and interpret math problems improve. This may help them better understand math problems and develop strategies to solve the problems, thereby increasing their math skills. In addition, in a classroom with higher Instructional Support, teachers not only facilitate children's language skills, but also provide children with opportunities that encourage analysis and reasoning skills, which are beneficial to children's math development.

Interaction between language status teacher-child interactions on children's achievement

The current study added important evidence to the extant research literature on examining whether the association between teacher-child interactions and achievement differ between monolingual English-speaking children and dual language learning children. The current study only found interactions between Classroom Organization and children's language status, as well as Instructional Support and children's language status on their math skills. The differences occurred when children were in classrooms with higher quality Classroom Organization or Instructional Support. Specifically, though both monolingual and dual language children demonstrated higher math skills as the quality of Classroom Organization and Instructional Support increased, respectively, dual language learning children's Math skills were higher compared to monolingual English-speaking children. Previous studies have indicated that dual language learners show larger gains in academic skills when they were in high-quality classrooms compared to monolingual English-speaking children (Burchinal et al., 2012). Other findings also provide evidence that positive teacher-child interactions are related to children's achievement across cultures (Hu et al., 2017; Hu et al., 2019). As dual language learning children may need to devote more attention to class instruction due to their language deficiency, a well-organized classroom can help them to maintain their attention on information needed for mathematical problem solving (Fuhs et al., 2015; McClelland & Cameron, 2019). Furthermore, there are more materials and resources for children to explore in a classroom with higher Classroom Organization. By exploring a variety of materials in the classroom, such as poster, blocks, and books, children may have more opportunities to develop their math skills. In a classroom where Classroom Organization is high, teachers may utilize numerous materials and provide opportunities to expose children to various math concepts, such as learning shapes and space by using blocks or games, which may help to build children's math skills.

Furthermore, in a classroom with higher Instructional Support, it is possible that dual language learning children tend to engage in interactions that are lower in linguistic complexity thus providing less language stimulation compared to their monolingual peers (Langeloo et al., 2019). In classrooms with higher Instructional Support, teachers consistently promote higher-order thinking, expand learning opportunities, and provide children with rich language stimulation, creating an environment is critically important to dual language learning children's language development and learning. As stated, children need to understand and identify the text of math problem before solving it. When their language skills improve, their abilities to comprehend the text of math problems increase. Also, in a higher Instructional Support classrooms, teacher may effectively promote children ‘s analysis and reasoning skills by focusing on different learning activities, such as asking children to compare and classify the similarities and differences between objects, guess and make prediction based on provided cues, which are related to children's math skills.

Unfortunately, the current study did not find interactions between teacher-child interactions and children's language status on any of the language skills. This is in line with the results of previous studies indicating no difference between monolingual Spanish-speaking children and dual language children on the strength of the association between teacher-child interactions and achievement (Downer et al., 2012). Studies examining the association between classroom quality and achievement for Latino dual language learners suggested that providing dual language children with opportunities to interact in their primary language in classrooms, even at relatively low level of instruction in their native language, was related to their academic skills and cognitive development (Burchinal et al., 2012; White et al., 2020). It is possible that in the current study, classroom instruction was primarily in English. Although classroom teachers may have provided plenty of opportunities to expand children's learning and participation, due to language deficiency, dual language learners may not have been able to fully understand the instruction and engage in learning. Therefore, Instruction Support provided by teachers may not have been enough to have an impact on dual language learners' receptive language and literacy skills in the current study. Given the increase in dual language learners in early childhood settings, there are relatively few studies examining how associations between teacher-child interactions differ across children's language status and thus impact their learning. More research is needed to increase our understanding of strategies to provide better support tailored to the cultural and linguistic needs of DLL children.

Limitations and future directions

Despite the contribution of the current study, there are limitations. First, the criteria used for defining DLL children in the current may not be rigorous enough to capture the characteristics of dual language learners. Due to limited information regarding children's language status, children were categorized as monolingual English-speaking children if they primarily spoke English at home as reported by the parents, otherwise, they were categorized as dual language learning children. This criterion only provides a rough estimate of DLL status, which may not be representative of DLLs across other nations (White et al., 2020). There is a need for future study to include more comprehensive information regarding DLL status, such as the onset of second language development, duration of language exposure and language proficiency (Downer et al., 2012). Second, like many studies examining teacher-child interactions or classroom quality, the CLASS observations were conducted within one single day because of limited data collectors and resource. It is likely that the one-day observation may not fully capture the feature and quality of teacher-child interactions. More frequent observations across different time points would have provided a more representative picture of the interactions between the teachers and students (Goble & Pianta, 2017). Third, while there is abundant positive evidence on the usefulness of the CLASS observation tool in studying teacher-child interactions in early childhood settings, researchers have argued that the CLASS is not sufficiently enough to capture the unique aspects of interactions between DLLs and teachers (Downer et al., 2012). It is suggested that ethnically and linguistically diverse children may require a different assessment that takes their cultural backgrounds and experiences into consideration (Downer et al., 2012). Future studies examining the issue of teacher-child interactions should consider an additional assessment that measure teacher-child interactions to use in conjunction with the CLASS observation tool, to gain a more thorough picture of the interactions between teachers and DLLs in classrooms.

References

Bihler, L.-M., Agache, A., Schneller, K., Willard, J. A., & Leyendecker, B. (2018). Expressive Morphological Skills of Dual Language Learning and Monolingual German Children: Exploring Links to Duration of Preschool Attendance, Classroom Quality, and Classroom Composition. *Frontiers in Psychology*, *9*, 888. https://doi.org/10.3389/fpsyg.2018.00888

Bossong, L., & Keller, H. (2018). Cross-cultural value mismatch in German day care institutions: Perspectives of migrant parents and day care teachers. *International Journal of Psychology*, *53*(S2), 72–80. https://doi.org/10.1002/ijop.12559

Bulotsky-Shearer, R. J., Bell, E. R., Carter, T. M., & Dietrich, S. L. (2014). Peer play interactions and learning for low-income preschool children: The moderating role of classroom quality. *Early Education and Development*, *25*(6), 815-840. https://doi.org/10.1080/10409289.2014.864214

Burchinal, M., Field, S., López, M. L., Howes, C., & Pianta, R. (2012). Instruction in Spanish in pre-kindergarten classrooms and child outcomes for English language learners. *Early Childhood Research Quarterly*, *27*(2), 188-197. https://doi.org/10.1016/j.ecresq.2011.11.003

Burchinal, M., Howes, C., Pianta, R., Bryant, D., Early, D., Clifford, R., & Barbarin, O. (2008). Predicting child outcomes at the end of kindergarten from the quality of pre-kindergarten teacher–child interactions and instruction. *Applied Development Science, 12*(3), 140-153. https://doi.org/10.1080/10888690802199418

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2), 282–298. https://doi.org/10.1111/j.1467-7687.2008.00675.x

Carr, R. C., Mokrova, I. L., Vernon-Feagans, L., & Burchinal, M. R. (2019). Cumulative classroom quality during pre-kindergarten and kindergarten and children's language, literacy, and mathematics skills. *Early Childhood Research Quarterly*, *47*, 218–228. https://doi.org/10.1016/j.ecresq.2018.12.010

Choi, J. Y., Castle, S., Williamson, A. C., Young, E., Worley, L., Long, M., & Horm, D. M. (2016). Teacher–Child Interactions and the Development of Executive Function in Preschool-Age Children Attending Head Start. *Early Education and Development*, *27*(6), 751–769. https://doi.org/10.1080/10409289.2016.1129864

Day, S. L., Connor, C. M., & McClelland, M. M. (2015). Children's behavioral regulation and literacy: The impact of the first grade classroom environment. *Journal of School Psychology*, *53*(5), 409–428. https://doi.org/10.1016/j.jsp.2015.07.004

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do". *Developmental Psychobiology*, *29*(4), 315–334. https://doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Downer, J. T., López, M. L., Grimm, K. J., Hamagami, A., Pianta, R. C., & Howes, C. (2012). Observations of teacher–child interactions in classrooms serving Latinos and dual language learners: Applicability of the Classroom Assessment Scoring System in diverse settings. *Early Childhood Research Quarterly*, *27*(1), 21-32. https://doi.org/10.1016/j.ecresq.2011.07.005

Dunn, L. M., & Dunn, D. M. (2007). PPVT-4: Peabody picture vocabulary test. Pearson Assessments.

Edyburn, K. L., Quirk, M., & Oliva-Olson, C. (2019). Supporting Spanish–English Bilingual Language Development Among Latinx Dual Language Learners in Early Learning Settings. *Contemporary School Psychology, 23*(1), 87–100. https://doi.org/10.1007/s40688-018-0209-7

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessments and teacher ratings. *Journal of Educational Psychology*, *107*(1), 207–221. https://doi.org/10.1037/a0037366

Goble, P., & Pianta, R. C. (2017). Teacher–child interactions in free choice and teacher-directed activity settings: Prediction to school readiness. *Early Education and Development, 28*(8), 1035-1051. https://doi.org/10.1080/10409289.2017.1322449

Hamre, B., Hatfield, B., Pianta, R., & Jamil, F. (2014). Evidence for General and Domain-Specific Elements of Teacher–Child Interactions: Associations With Preschool Children's Development. *Child Development*, *85*(3), 1257–1274. https://doi.org/10.1111/cdev.12184

Hatfield, B. E., Burchinal, M. R., Pianta, R. C., & Sideris, J. (2016). Thresholds in the association between quality of teacher–child interactions and preschool children's school readiness skills. *Early Childhood Research Quarterly, 36*, 561–571. https://doi.org/10.1016/j.ecresq.2015.09.005

Hu, B. Y., Fan, X., Wu, Z., LoCasale-Crouch, J., Yang, N., & Zhang, J. (2017). Teacher-child interactions and children's cognitive and social skills in Chinese preschool classrooms. *Children and Youth Services Review*, *79*, 78-86. https://doi.org/10.1016/j.childyouth.2017.05.028

Hu, B. Y., Fan, X., Wu, Y., LoCasale-Crouch, J., & Song, Z. (2019). Contributions of Teacher–Child Interaction Quality to Chinese Children’s Development in the Early Childhood Years. *Early Education and Development*, *30*(2), 159-177. https://doi.org/10.1080/10409289.2018.1544809

Langeloo, A., Mascareño Lara, M., Deunk, M. I., Klitzing, N. F., & Strijbos, J.-W. (2019). A Systematic Review of Teacher–Child Interactions With Multilingual Young Children. *Review of Educational Research*, *89*(4), 536–568. https://doi.org/10.3102/0034654319855619

Mashburn, A., Pianta, R., Barbarin, O., Bryant, D., Hamre, B., Downer, J., . . . Howes, C. (2008). Measures of Classroom Quality in Prekindergarten and Children's Development of Academic, Language, and Social Skills. *Child Development*, *79*(3), 732-749. http://www.jstor.org/stable/27563514

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children’s early academic lives. *Early Childhood Research Quarterly*, *46*, 142–151. https://doi.org/10.1016/j.ecresq.2018.03.014

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M., & Morrison, F. J. (2016). The development of self-regulation across early childhood. *Developmental Psychology*, *52*(11), 1744–1762. https://doi.org/10.1037/dev0000159

Nores, M., Barnett, W.S., Jung, K., Joseph, G. & Bachman, L. (2019). Year 4 report: Seattle Preschool Program evaluation. New Brunswick, NJ: National Institute for Early Education Research & Seattle, WA: Cultivate Learning

Park, J., Ellis Weismer, S., & Kaushanskaya, M. (2018). Changes in executive function over time in bilingual and monolingual school-aged children. *Developmental Psychology*, *54*(10), 1842–1853. https://doi.org/10.1037/dev0000562

Park, M., O'Toole, A., & Katsiaficas, C. (2017). Dual Language Learners: A National Demographic and Policy Profile. Fact Sheet. *Migration Policy Institute*. Retrieved from file:///C:/Users/arbo0/Downloads/DLL-FactSheet-US-FINAL%20(1).pdf

Pianta, R. C., LaParo, K. M., & Hamre, B. K. (2008). Classroom assessment scoring system: pre-K (CLASS pre-K). Baltimore, MD: Brookes.

Reilly, S. E., Johnson, A. D., Luk, G., & Partika, A. (2019). Head Start Classroom Features and Language and Literacy Growth among Children with Diverse Language Backgrounds. *Early Education and Development*, *31*(3), 354–375. https://doi.org/10.1080/10409289.2019.1661935

Tenenbaum, H. R., & Ruck, M. D. (2007). Are teachers' expectations different for racial minority than for European American students? A meta-analysis. *Journal of Educational Psychology*, *99*(2), 253–273. https://doi.org/10.1037/0022-0663.99.2.253

Tran, C. D., Arredondo, M. M., & Yoshida, H. (2015). Differential effects of bilingualism and culture on early attention: a longitudinal study in the US, Argentina, and Vietnam. *Frontiers in Psychology*, *6*, 795. https://doi.org/10.3389/fpsyg.2015.00795

Vandenbroucke, L., Spilt, J., Verschueren, K., Piccinin, C., & Baeyens, D. (2017). The Classroom as a Developmental Context for Cognitive Development: A Meta-Analysis on the Importance of Teacher–Student Interactions for Children's Executive Functions: *Review of Educational Research*. https://doi.org/10.3102/0034654317743200

Vernon-Feagans, L., Mokrova, I. L., Carr, R. C., Garrett-Peters, P. T., & Burchinal, M. R. (2019). Cumulative years of classroom quality from kindergarten to third grade: Prediction to children's third grade literacy skills. *Early Childhood Research Quarterly*, *47*, 531–540. https://doi.org/10.1016/j.ecresq.2018.06.005

Weiland, C., Ulvestad, K., Sachs, J., & Yoshikawa, H. (2013). Associations between classroom quality and children's vocabulary and executive function skills in an urban public prekindergarten program. *Early Childhood Research Quarterly*, *28*(2), 199–209. https://doi.org/10.1016/j.ecresq.2012.12.002

White, L. J., Fernandez, V. A., & Greenfield, D. B. (2020). Assessing Classroom Quality for Latino Dual Language Learners in Head Start: DLL-Specific and General Teacher-Child Interaction Perspectives. *Early Education and Development*, 1-29. https://doi.org/10.1080/10409289.2019.1680785

Woodcock, R. W., McGrew, K. S., Mather, N., & Schrank, F. (2001). Woodcock-Johnson III NU tests of achievement. Rolling Meadows, IL: Riverside Publishing.

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*(1), 297. https://doi.org/10.1038/nprot.2006.46

Study 3 - Testing the Thresholds in the Association between Teacher-child Interactions and School Readiness among Monolingual English Speaking and Dual Language Children

Introduction

Teacher-child interactions, most commonly measured by the quality of interactions between teacher and children, referred to as classroom quality, are believed to play a critical role in children's development during early childhood (Carr et al., 2019; Downer et al., 2012; Burchinal et al., 2010). According to previous studies, evidence suggests that high quality teacher-child interactions promote children's positive outcomes and have long-lasting positive effects on children's development (Carr et al., 2019; Hu et al., 2020; Hamre et al., 2014; Mashburn et al., 2008; Reilly et al., 2019). Specifically, children in classrooms where teachers are sensitive and responsive to children's needs, provide clear expectations and promote children's higher order thinking and language skills tend to have better school readiness.

However, some researchers have claimed that teacher-child interactions might not have substantial positive effects on children's school readiness until these interactions meet certain quality levels (Weiland et al., 2013; Guerrero-Rosada et al., 2021). Several studies have found small-to-moderate or null relationships between teacher-child interactions and children's outcomes (Choi et al., 2016; Vernon-Feagans et al., 2019). Similarly, studies conducted outside of the United States, obtained results indicating effect sizes of the associations between teacher-child interactions and child outcomes were small (Leyva et al., 2015). That is, the associations between teacher-child interactions and children's outcomes were generally weak (Weiland et al., 2013; Burchinal et al., 2014).

In line with these findings, a study assessing teacher-child interactions among Spanish speaking and dual language learning (DLL) children found a null relationship between teacher-child interactions and children's language skills (White et al., 2020). Dual language learners (DLLs) are children who are simultaneously learning their home language as their primary language and another language as their second language (Burchinal et al., 2012; Bihler et al., 2018). Studies suggest that teachers may establish different interactions with these children because they may bring experiences to the classroom that involve different cultures with different norms and expectations (Langeloo et al., 2019). The disconnection between home language and school language can place DLLs at a disadvantage in classrooms (Reilly et al., 2019). With the increase of dual language children in the early childhood settings in the United States, understanding the association of teacher-child interactions among these children becomes important (Park et al., 2017).

To understand reasons regarding the low or null associations between teacher-child interactions and school readiness, researchers have adopted several approaches to understand the relationship (Li et al., 2019; Burchinal et al., 2014). These researchers have pointed out the possibility that there may be thresholds above which teacher-child interactions are related to children's school readiness (Burchinal et al., 2014; Hatfield et al., 2016; Li et al., 2019). Others have also suggested that the relationship between teacher-child interactions may be non-linear (Weiland et al., 2013; Leyva et al., 2015). Accordingly, teacher-child interactions may need to reach to certain thresholds in order to influence children's outcomes (Weiland et al., 2013). Given the growing evidence indicating the importance of high-quality classroom interactions on children's school readiness, identifying thresholds can be important for developing policies to properly allocate resources for quality improvement in preschools (Burchinal et al., 2010). The current study replicated previous studies testing whether there are threshold effects in determining the relationships between teacher-child interactions and preschoolers' school readiness. In addition, the current study extended previous studies by examining whether the threshold effects differed between English-speaking children and dual language learning children.

Associations between teacher-child interactions and child development

Executive function

Executive function is a broad construct encompassing multiple higher-order cognitive processes which involves monitoring and regulating of thoughts and behaviors to help individuals attain goal-directed behaviors (Meuwissen & Englund, 2016). Executive function depends on the coordination of multiple cognitive processes that help children understand and control their actions so as to react adaptively to the environment (Montroy et al., 2016). Studies of teacher-child interactions emphasize the importance of a teacher building affective relationships with the children, providing clear expectations and structure, and increasing children's engagement and exploration in the classroom to develop their executive function skills (Choi et al., 2016; Vandenbroucke et al., 2018).

The Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2008) is an observational tool that measures classroom quality by observing teacher-child interactions in three domains, which are Emotional Support, Classroom Organization and Instructional Support (Von Suchodoletz et al., 2014; Pakarinen et al., 2010). The CLASS has been widely used in the field of early childhood education to understand teacher-child interactions. Emotional Support encompasses teacher's sensitivity in regard to children's needs. Classroom Organization is characterized by a classroom that is well-organized and with predictable schedule. Instructional

Support emphasized teacher's effort to expand children's higher order thinking and provide learning opportunities. According to the manual, classrooms are regarded as high-quality Emotional Support, Classroom Organization or Instructional Support when scored between 6 and 7, medium-quality when scored between 3 and 5, and low-quality when scored between 1 and 2 (CLASS; Pianta, La Paro, & Hamre, 2008). Several studies have found that children tend to have higher gains in inhibitory control and working memory when they are in a classroom with higher Emotional Support and Classroom Organization (Choi et al., 2016; Hamre et al., 2014; Weiland et al., 2013).

Evidence supports this association suggesting that children in a classroom where teachers are supportive and clear expectations are provided, may feel less stress and can devote more attention to the classroom activities allowing them to practice regulating skills, which are essential to strengthening executive function (Vandenbroucke et al., 2018). Hatfield et al. (2016) also found that children demonstrated higher executive function skills when in high Emotional Support classrooms compared to children in classrooms with lower Emotional Support. Studies examining the association between teacher-child interactions and executive function among Latino dual language learners found similar results (Downer et al., 2012).

A number of studies have found that higher teacher-child interactions, especially in the domain of Instructional Support, are related to children's executive function development. A higher Instructional Support classroom is regarded as an environment where teachers use various instructional activities to facilitate children's higher order thinking skills and language facilitation and stimulation techniques to expand their learning. Teacher's efforts to promote children's higher-order thinking skills and enrich their experiences may facilitate children's executive function (Fay-Stammbach et al., 2014). Though these correlations tended to be small, evidence has shown that Instructional Support was positively related to children's executive function development (Hamre et al., 2014; Hu et al., 2020; Hatfield et al., 2016; Leyva et al., 2015) and executive function gain (Cadima et al., 2016).

However, mixed evidence exists. There is some evidence indicating that teacher-child interactions are not associated with children's executive function development. Choi et al., (2016) did not find an association between Instructional Support and executive function while Hamre et al., (2014) found that Emotional Support negatively predicted children's gain in inhibitory control. Similarly, another recent study did not find Classroom Organization contributed to children's executive function longitudinally (Hu et al., 2020). For dual language learners, Downer et al., (2012) did not find that Instructional Support contributed to children's executive function development. Studies indicating small or non-linear relationship between classroom quality and executive function have suggested that the relationship between teacher-child interactions and executive function may be non-linear (Hatfield et al., 2016). Several studies therefore tested both linear and quadratic trends between teacher-child interactions and executive function. Weiland et al., (2013) found there were no linear relationships between classroom quality as measured by CLASS and inhibitory control, but there were significant quadratic associations between the three CLASS domains and inhibitory control. However, another study did not find any quadratic relationships between classroom quality and executive function (Leyve et al., 2015). Due to the small or null relationships between classroom quality and executive function, several researchers have suggested that it is possible that children's outcomes might be different according to levels of teacher-child interactions (Burchinal et al., 2010; Weiland et al., 2013, Hatfield et al., 2016).

Language, literacy, and math skills

There are a number of studies that have examined the impact of teacher-child interactions on children's school readiness in early childhood (Carr et al., 2019; Hu et al., 2019; Mashburn et al., 2008; Reiley et al., 2019). Several studies have demonstrated that Instructional Support predicted gains in preschoolers' language and literacy skills (Hamre et al., 2014) and was associated with children's later oral and written language, and math skills (Hamre et al., 2008). Studies conducted outside of the United States also found positive linear associations between Instructional Support and children's writing (Leyva et al., 2015), though the effect sizes of the associations were small. From a recent longitudinal study conducted in China (Hu et al., 2020), findings showed that even Instructional Support was relatively low compared to Emotional Support and Classroom Organization, Instructional Support not only positively predicted children's language and math skills over time, but also was predictive of children's math growth.

While results from a number of studies suggest high quality teacher-child interactions are important for child development (Carr et al., 2019; Mashburn et al., 2008; Vernon-Feagans et al., 2019), several studies have not found associations between teacher-child interactions and children's school readiness. Findings from these studies indicated no linear associations between Emotional Support and Classroom Organization on receptive language and math skills (Leyva et al., 2015; Hu et al., 2020; Mashburn et al., 2008). Studies conducted with Latino dual language children also found null relationships between teacher-children interactions and children's language skills (White et al., 2020). Another study even found that Classroom Organization was negatively correlated to children's math skills over time (Hu et al., 2020). These null or negative results have led researchers to question whether the association between classroom quality and child outcomes was non-linear (Burchinal et al., 2014; Weiland et al., 2013). Leyva et al., (2015) tested for both linear and quadratic associations between teacher-child interactions and child outcomes using spine regression and only found linear relationships between Instructional Support and gains in children's writing, with a small effect size of the association. In addition, there were positive quadratic associations between Classroom Organization and gains in language and numeracy skills, indicating that the relationship between Classroom Organization and child outcomes were stronger when teachers provided clearer expectations and structure.

Researchers have suggested that it is possible the quality of teacher child interactions have to reach some threshold to have an impact on children's development (Burchinal et al., 2010, 2014). That is, children need to be in a classroom where teacher-child interactions are of a certain level of quality in order to show positive effects on their development. Furthermore, other researchers have suggested the small magnitude of the linear association between teacher-child interactions and child outcomes might indicate the possibility of non-linear association between these variables (Weiland et al., 2013; Leyva et al., 2015).

Evidence of thresholds in the relationships of teacher-child interactions and children's school readiness

Studies examining associations between teacher-child interactions and child's school readiness have found that teachers tended to score higher on Emotional Support, followed by Classroom Organization, and had lower scores on Instructional Support (Hu et al., 2020; Von Suchodoletze et al., 2014; Leyva et al., 2015). Further, several studies have employed piecewise regression to address the thresholds issue regarding the associations between teacher-child interactions and child outcomes and found inconsistent results (Burchinal et al., 2010; Burchinal et al., 2014; Hatfield et al., 2016; Weiland et al., 2013).

Results from studies examining whether children demonstrated higher school readiness when they were in high-quality classrooms have found inconsistent evidence for quality thresholds across different domains. For Emotional Support, researchers used a cut point of 5 for Emotional Support and found that children had larger increases in social skills when they are in a high-quality classroom, but there is no evidence suggesting thresholds were associated with teacher-child interactions and children's school readiness (Burchinal et al., 2014). Similarly, Weiland et al. (2013) found a threshold effect between children's receptive language and emotional support with a cut point of 5.13, whereas in another study, Burchinal et al., (2010) did not find any association between emotional support and children's school readiness using the same cut point. In another study using a higher cut point of 6 for emotional support, Hatfield et al., (2016) found children demonstrated higher phonological awareness when teachers provided high levels of responsive and sensitive interaction. In contrast, the association between Emotional Support and children's phonological awareness was weaker when classrooms were below the cut point 6. But they did not find evidence indicating signification relationships between language skills and any of the three CLASS domains (Hatfield et al., 2016).

For Classroom Organization, researchers did not find any threshold effects between Classroom Organization and school readiness when using a cut point of 4.29 (Weiland et al., 2013) or 5 (Burchinal et al., 2010), but Burchinal et al., (2014) found children had larger increases in social skills when they were in a classrooms scored at or higher than 5 for Classroom Organization. However, in the same study, there was no evidence suggesting thresholds associated with teacher-child interactions and children's receptive language, literacy skills and executive function skills (Burchinal et al., 2014). Hatfield et al. (2016) used a higher score of 6 for Classroom Organization and found children demonstrated higher phonological awareness when teachers consistently provided clear behavioral expectations, characterized by high classroom organization. In regard to Instructional Support, a cut point of 3.25 was used for Instructional Support and children in higher Instructional Support classrooms tended to have higher scores in expressive language and math skills, and the magnitude of the association was stronger in higher quality classroom than in lower quality classrooms (Burchinal et al., 2010). Additionally, studies using a lower cut point of 3 (Burchinal et al., 2014) or a higher cut point of 3.9 (Weiland et al., 2013) did not find any threshold effect between Instructional Support and children's language and literacy skills.

Though there remains inconsistency among the thresholds between teacher-child interactions and school readiness, several studies have suggested that children tend to demonstrate better school readiness when teachers are consistently responsive in their interactions with children, manage classroom structure and intentionally enhance children's higher order thinking (Carr et al., 2019; Hu et al., 2020; Weiland et al., 2013; Reiley et al., 2019). Studies examining classroom features among English speakers and Spanish-speaking dual language learns found that regardless of language status, higher Instructional Support and Classroom Organization are associated with higher language and literacy skills (Reiley et al., 2019). In addition, in the same study, Reiley et al., (2019) found that dual language learners benefited more in their receptive language development when teachers provided a higher emotionally supportive and warm environment.

According to Burchinal et al., (2010), identifying possible threshold allows us to understand whether the minimum level at which point positive relationships between classroom quality and child outcomes occurs; additionally, it enables educators to ensure that children receive at least the minimum level of quality in preschool. Therefore, the current study explored whether there was evidence of thresholds in the relationship between teacher-child interactions and children's school readiness. In addition, the current study extended previous studies by developing an understanding as to whether threshold effects differed between monolingual English-speaking children and dual language children.

Current Study

Although previous studies examining the relationship between teacher-child interactions and school readiness have provided evidence of threshold effects in predicting children's school readiness, the results are mixed. In the present study, teacher-child interactions were measure using the CLASS observation tool that includes three domains, Emotional Support, Classroom Organization, and Instructional Support. School readiness is defined as children's receptive language, literacy, math, and executive function skills. The current study replicated previous studies examining threshold effects to test whether associations between each CLASS domain were stronger at higher quality levels of teacher-child interactions. Instead of using a score of 5 or 6 for Emotional Support and Classroom Organization, and a score of 3 for Instructional Support as was done in previous studies, the current study used the mean score of each domain as cut-points. The cut-points in the study were chosen for two reasons. First, most classrooms in the current study received relatively high scores on Emotional Support and Classroom Organization, using a score of 5 or 6 would result in unbalanced sample size between the higher and lower classrooms (93% and 70% children received scores above 6 on Emotional Support and Classroom Organization, respectively). Second, the mean score was chosen so that there was a more balanced sample size between the higher and lower classrooms, with around 40%-60% of the children falling into either lower or higher classrooms, respectively. In addition, these cut-points could also better reflect the threshold effects in the current sample. The current study also extended previous research by examining whether threshold effects differ between English-speaking children and dual language learning children. Previous studies testing threshold effects have mainly focused on English-speaking children. Given that English-speaking children and dual language learning children have different characteristics and backgrounds, the effects of teacher-child interactions may be different for each population. Attention as to whether the association between teacher-child interactions and school readiness differs between English speaking children and dual language learners may be beneficial to design classroom environments that benefit both populations socially and academically. Therefore, the main purpose of the current study was to investigate evidence of thresholds in the association between CLASS domains measuring teacher-child interactions and school readiness, and whether the threshold effects differed between English-speaking children and dual language learning children. Specifically, the present study proposed the following hypotheses,

Hypothesis 1: There are threshold effects between levels of teacher-child interactions measured by CLASS and school readiness.

Hypothesis 2: There are different threshold effects between levels of teacher-child interactions measured by CLASS and school readiness among English-speaking children and dual language learning children.

Method

Participants

The curry study was part of a larger project conducted in a large urban area in the north western part of the United States that examined classroom quality and how the quality affected children's development (Nores et al., 2019). A total of 834 children (48% male and 52% female) completed the full battery of assessments at both pre- and post-test of the assessments were included in the study. On average, children were between 3 and 5 years of age (*Mean* = 4.42 years old, *SD* = 0.5) at the start of the study. Children attended 82 classrooms across 59 preschools and family child-care centers. These classrooms used either Creative Curriculum or High Scope Curriculum. Participants in the study were ethnically and racially, 26.7% were Black or African-American, 23% were white, 18.8% were Asian, 14.9% were two or more races, 14.5% were Hispanic or Latino, 0.6% were Native Hawaiian or Other Pacific Islander and 0.5% were American Indian or Alaskan Native. Among families reporting primary language spoken at home, 72% reported English as their primary language spoken at home and 28% reported a language other than English spoken at home, including Mandarin, Somali, Cantonese, Spanish or other languages. Median house income was around $51,792 (Mean = $66,501; range = $1493 to $ 1365,429), with 22% of the families declined to report their income.

Procedure

Data collection occurred from Fall 2018 to Spring 2019. Children were first assessed in the Fall for pre-test and again at the end of the school year in Spring 2019 for post-test, with a minimum of six months lapsing between the pre- and post-test. Consent forms were distributed to families and only children with parental consent were assessed. For individual child assessments, data collectors visited the schools and conducted the one-on-one assessments in a quiet place in the school. Children included in the current study were all assessed in English. An interpreter who spoke the child’s primary language was present to conduct informed consent with the child if needed. Prior to beginning data collection, all data collectors received a two-day training on the assessments and were given several days to practice prior to the data collection. To ensure data collector reliability as assessors, each data collector was then observed by the project’s assessment. Data collectors were required to meet reliability criteria at 90% accuracy at the beginning of the study and then reliability was re-established after the completion of several assessments. Training and reliability were complete prior to both Spring and Fall data collection periods. The full battery of assessments included Peg Tapping Test (PT; Diamond & Taylor, 1996), Dimensional Change Card Sort Task (DCCS; Zelazo, 2006), Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV; Dunn & Dunn, 2007), and the Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III; Woodcock et al., 2001), Letter Word Identification and Applied Problems subtests. Children were assessed for 15-30 minutes depending on the child's performance. Most children finished all the tasks on the same day of the assessment and children received a sticker as an appreciation for their participation.

Classroom quality was measured between the pre- and post- individual child assessments in the Winter of 2019 using the Classroom Assessment Scoring System Pre-K observational tool (CLASS Pre-K; Pianta et al., 2008). Each classroom was observed by a trained data collector. The observations began when the children arrived the classroom and usually ended at noon depending on the class schedule. In the current study, each classroom was observed in four 20 minutes segments, with 10-minute coding periods between each cycle. An observation cycle lasted an average of 20 minutes, this amounted to around 80 minutes of observation per classroom. The score of each 10 CLASS dimension was calculated for approximately 10 minutes after each cycle and before beginning of the next observation cycle. Prior to conducting the CLASS, all data collectors were trained by a CLASS certified trainer and met the Teachstone reliability certification requirements prior to the observation.

Measures

Individual assessments

Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV). The Peabody Picture Vocabulary Test—Fourth Edition (PPVT-IV; Dunn & Dunn, 2007) was used to measure children's receptive language skills in English. Each test item requires the child to look at four picture and point to the picture or say the number of the picture based on the data collector's instruction. There are a total of 228 items and children receive 1 point if they choose the correct answer. The test is standardized to a mean of 100 and a standard deviation of 15. The test-retest reliability ranges from 0.91 to 0.94, and the published split-half reliabilities for preschool children range between .93 - .97 (Dunn & Dunn, 2007).

Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III). The Letter-Word Identification (LWID) and Applied Problems (AP) subtests of the Woodcock-Johnson Psycho-Educational Battery—Third Edition (WJ-III; Woodcock, McGrew, Mather, & Schrank, 2001) were used in the current study. The Letter-Word Identification subtest was used to measure children's literacy skills. The task is an untimed task in which children are asked to complete literacy tasks of increasing difficulty beginning with matching letters and words, verbally identifying letters, and finally reading words. The Applied Problems subtest was used to measure children's skills in analyzing and solving applied math problems. In the task, children were asked to perform mathematical calculations in response to assessor's directions. The test is standardized to a mean of 100 and a standard deviation of 15. The estimated test-retest reliability for children is 0.90 and published reliabilities of 0.91 in the age 5 to 19 range (Woodcock et al., 2001).

Peg Tapping Test (PT). Children's executive function skills were measured using the Peg Tapping test (PT; Diamond & Taylor, 1996). The Peg Tapping test, requires children to practice inhibition control as they must hold things in mind as they complete assessment tasks. In the task, children are asked to tap once when the assessor taps twice and tap twice when the assessor taps once. Children must correctly response to two consecutive practice trials to continue to the formal assessment. Children are given a -1 score if they are unable to correctly respond to the two consecutive practice trials, and the assessment is discontinued. For the formal assessment, there are 8 one-tap and 8 two-tap trials presented in random sequence, with a total of sixteen trials conducted. A score of 1 score is given for each correct response and a score of 0 for each incorrect response. Scores range from -1 to 16 with higher scores indicating higher levels of executive function in the area of inhibitory control. The Peg Tapping test has been shown to have good internal reliabilities (Cronbach's α = 0.93; Hatfield et al., 2016) and it has shown moderate construct validity with other executive function tasks, r =.42 (Head-Toes-Knees-Shoulders task, HTKS) (Fuhs et al., 2015).

Dimensional Change Card Sort Task (DCCS). The Dimensional Change Card Sort Task (DCCS; Zelazo, 2006) involves sorting pictures based on each of three dimensions (color, shape, and both), and measures children's overall executive function in the area of working memory, inhibition and shifting. There are 6 items for each of the first two subtest and 12 items for the last subtest, for a total of 24 items. Children receive a score of 1 if they produce the correct response and 0 if they respond incorrectly, with 24 being the total achievable score. The task has been shown to have good internal consistency (Cronbach's α = 0.85; Duncan et al., 2017) and test-retest reliability r = .63. (McClelland et al., 2014).

Teacher-child Interactions

Classroom Assessment Scoring System Pre-K (CLASS Pre-K). Teacher-child interactions was observed in the Winter of 2019 using the *Classroom Assessment Scoring System Pre-K (CLASS Pre-K*; Pianta et al., 2008). As noted earlier, the CLASS is an observational measure designed to assess teacher-child interactions as a measure of classroom quality. The CLASS includes 10 dimensions divided amongst three domains: Emotional Support, Instructional Support and Classroom Organization. The Emotional Support domain includes four dimensions: Positive Climate, Negative Climate, Teacher Sensitivity, and Regard for Student Perspectives. The Classroom Organization domain includes three dimensions: Productivity, Behavior Management, and Instructional Learning Formats. The Instructional Support domain includes three dimensions: Concept Development, Quality of Feedback, and Language Modeling. Rating were made based on a 7-point Liker scale ranging from "low" (score 1) to "high" (score 7). According to the manual, 1 or 2 indicates low quality, 3 to 5 indicates medium quality, and a score of 6 or 7 indicates high quality teacher-child interactions. Dimension scores are averaged to obtain an average classroom quality score for each domain. Prior to conducting classroom observations, CLASS observers were trained by a CLASS certified trainer and met the Teachstone reliability certification requirements. On average, CLASS reliability agreement percentages for data collectors ranged between 92-98% (Nores et al., 2019). Reliability estimate from other study has shown adequate reliability, the internal consistency of each domain Emotional Support, Classroom Organization and Instructional Support were 0.89, 0.79, 0.82, respectively (Downer et al., 2012).

Analysis Plan

Three sets of analyses were conducted to understand the threshold effects on the association between teacher-child interactions and children's school readiness. First, descriptive analyses that estimated the means, standard deviations, and correlations for the variables in the study were executed. Second, to address our first research question, two level random-intercept, piecewise regression models using multilevel modeling were tested to estimate whether CLASS domain scores were stronger predictors of school readiness in classrooms rating higher than lower in teacher-child interactions. The covariates in the analyses included a pre-test, child gender (Female was coded 1 while male was coded 0), age, and language status. To choose the cut points, the mean scores for each CLASS domain were used in the current study, with a high-quality score of 6.59 defining higher quality for Emotional Support, a high-quality score of 6.23 defining higher quality for Classroom Organization, and a mid-quality score of 3.19 defining higher quality for Instructional Support. Given that the average score of each CLASS domain in the current study was relatively high, the current study did not utilize a cut point of 5 or 6 for Emotional Support and Classroom Organization, and 3 for Instructional Support as cut points as were chosen in previous studies (Burchinal et al., 2014; Hatfield et al., 2016). Specifically, the general model used in the current study is shown below,

Level 1 model (students):

$$Spring\ achievement_{ij} = \beta_{0j} + \beta_{1j}\ (Fall\ achievement_{ij}) + \beta_{2j}\ (Language\ Status_{ij}) + \beta_{3j}\ (Age_{ij}) + \beta_{4j}\ (Female_{ij}) + r_{ij}$$

Level 2 model (classroom):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\ (CLASS_j) + \gamma_{02}\ (CLASS_j) * (High\text{-}quality\ CLASS_j) + u_{0j}$$

where Spring achievement$_{ij}$ is the *i*th child's spring achievement score for the *j*th classroom. γ_{00} is the overall intercept; β_{1j} is the coefficients for child's fall achievement; $\beta_{2j}, \beta_{3j}, \beta_{4j}$ are the coefficients for child covariates, respectively. There were separate slopes estimated for each low- and high- quality teacher-child interactions for the *j*th classroom. *High-quality CLASS$_j$*

is a dummy variable, coded 1 when the CLASS score of *j*th classroom is equal or above the cut-point, and coded 0 when the CLASS score of *j*th classroom is below the cut-point chosen in the current study. γ_{01} represents the linear association between CLASS and child achievement in lower-quality classrooms; γ_{02} represents the increment to the slope for the quality among high-quality classrooms, that is, the linear association between CLASS and child achievement in higher-quality classrooms is $\gamma_{01} + \gamma_{02}$. u_{0j} is the random classroom intercept.

Finally, to answer the second research question – whether associations between quality of teacher-child interactions and school readiness differed by children's language status, children's language status was recoded into dichotomous indicators where 1 indicates monolingual English-speaking children and 0 indicates dual language learners. An interaction term between CLASS and children's language status was added to the model.

Missing Data

Overall, there was a relatively low amount of missing data across the variables in the study. For individual child assessment, missingness was 0.1% during the Fall and Spring for the PPVT, Woodcock-Johnson, Peg Tapping and DCCS (*Ns* = 2 – 7). There were no missing data for child age, language status, gender, and classroom-level observed teacher-child interactions. Missingness of child data were due to absence, child left the program, or child was unable to complete the assessments. These children were excluded from the current study, resulting in a final sample of 834 children in the study.

Results

Descriptive statistics

Descriptive statistics of children's Fall and Spring achievement scores are presented in Table 1. Table 2 provides descriptive statistics of teacher-child interactions as measured by thethree CLASS domains. According to the quality domains suggested by the manual (*CLASS Pre-K*; Pianta et al., 2008), with 1 or 2 indicates low quality, 3 to 5 indicates medium quality, and a score of 6 or 7 indicates high quality teacher-child interactions. As shown in Table 2, the scores for Emotional Support (M = 6.59, SD = 0.37) and Classroom Organization (M = 6.23, SD = 0.53) are relatively high, both falling into the high-quality range, while Instructional Support *(M = 3.19, SD = 0.82)* is low and falls into the medium-quality range based on the manual *(CLASS Pre-K*; Pianta et al., 2008). For Emotional Support and Classroom Organization, the scores ranged from moderate to high, and for Instructional Support, the scores ranged from low to medium.

Overall, 59% of children attended classrooms with high Emotional Support receiving score equal or higher than 6 (N = 76 classrooms, 91% of classrooms); Similarly, 55% of children attended classrooms with high Classroom Organization (N = 58 classrooms, 45% of classrooms) receiving scores equal or higher than 6. On the other hand, none of the children attended classrooms with high Instructional Support, 51% of children attended classrooms with medium Instructional Support (N = 42 classrooms, 51% of classrooms) receiving scores between 3 and 5, whereas 55% of children attended classrooms with low Instructional Support (N = 37 classrooms, 45% of classrooms) receiving scores between 1 and 2. Zero-order correlation between child achievement and each of the CLASS domains are provided in Table 3. As can be seen in Table 3, the CLASS scores tend to be correlated with children's math skills measured by WJ-AP and executive function measured by DCCS. In addition, there are positive correlations between each of the CLASS domains.

Table 1

Descriptive Statistics for Demographic Variables, PPVT, WJ and Executive Function

Demographics	Full sample (*N* = 834)			English-Speaking (*N* = 600)			Dual-Language (*N* = 234)		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Age (in years)	4.42	0.5	3.16-5.25	4.44	0.49	3.17-5.25	4.4	0.51	3.17-5.25
Gender (% male)	48%			48%			50%		
Fall									
PPVT	96.61	19.19	20-153	101.47	17.85	20-153	84.1	16.7	35-126
WJ - Letter word	101.99	14.17	63-169	102.02	13.89	63-160	101.91	14.87	63-169
WJ - applied problem	101.49	14.27	53-141	103.54	13.96	53-141	96.11	13.71	53-127
Peg Tapping	6.01	5.87	-1-16	6.58	5.93	-1-16	4.54	5.45	-1-16
DCCS	11.16	5.98	0-24	11.84	6.03	0-24	9.42	5.49	0-22
Spring									
PPVT	100.09	17.47	37-147	104.38	16.55	37-147	89.06	14.76	44-135
WJ - Letter word	102.26	14.4	57-175	101.86	14.39	57-175	103.26	14.41	69-161
WJ - applied problem	103.38	12.81	49-146	104.48	12.99	49-146	100.56	11.89	49-132
Peg Tapping	8.40	5.80	-1-16	8.62	5.80	-1-16	7.67	5.89	-1-16
DCCS	13.43	6.1	0-24	13.93	6.06	0-24	12.16	6.05	0-24

Note. PPVT = Peabody Picture Vocabulary Test; WJ - Letter word = Woodcock-Johnson Psycho-Educational Battery - Letter-Word Identification subtest; WJ - applied problem = Woodcock-Johnson Psycho-Educational Battery - Applied Problems subtest; DCCS = Dimensional Change Card Sort Task

Table 2

Descriptive Statistics for CLASS

CLASS	Full sample (*N* = 834)			Quality subdivided into segments					
				Lower (rang, N, %)			Higher (rang, N, %)		
	M	*SD*	Range						
Emotional Support	6.59	0.37	5.15-7.00	(1-6.58)	344	41%	(6.59-7)	490	59%
Classroom Organization	6.23	0.53	4.13-7.00	(1-6.22)	372	45%	(6.23-7)	462	55%
Instructional Support	3.19	0.82	1.5-5.33	(1-3.18)	460	55%	(3.19-7)	374	45%

Note: The cut-off score was 6.59 for Emotional Support, 6.23 for Classroom Organizaton, and 3.19 for Instructional Support.

Table 3

Zero-order Correlation between Variables (N = 834)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Fall PPVT	1												
2. Fall WJ-LWID	0.26 ***	1											
3. Fall WJ-AP	0.69 ***	0.38 ***	1										
4. Fall Peg Tapping	0.49 ***	0.20 ***	0.53 ***	1									
5. Fall DCCS	0.47 ***	0.14 ***	0.49 ***	0.52 ***	1								
6. Spring PPVT	0.84 ***	0.18 ***	0.68 ***	0.48 ***	0.47 ***	1							
7. Spring WJ-LWID	0.23 ***	0.81 ***	0.35 ***	0.14 ***	0.11 **	0.21 ***	1						
8. Spring WJ-AP	0.58 ***	0.38 ***	0.73 ***	0.44 ***	0.42 ***	0.63 ***	0.43 ***	1					
9. Spring Peg Tapping	0.39 ***	0.14 ***	0.48 ***	0.58 ***	0.41 ***	0.46 ***	0.15 ***	0.45 ***	1				
10. Spring DCCS	0.47 ***	0.12 ***	0.51 ***	0.49 ***	0.57 ***	0.50 ***	0.13 ***	0.48 ***	0.44 ***	1			
11. CLASS ES	0.05	0.01	0.07	0.07	0.13 ***	0.07	0.05	0.14 ***	0.06	0.13 ***	1		
12. CLASS CO	0.05	0.02	0.12 ***	0.06	0.12 ***	0.11 **	0.06	0.16 ***	0.06	0.14 ***	0.71 ***	1	
13. CLASS IS	0.03	0.05	0.08 *	-0.01	0.06	0.07 *	0.09 **	0.14 ***	0.00	0.11 ***	0.38 ***	0.68 ***	1

$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Note. PPVT = Peabody Picture Vocabulary Test; WJ - LWID= Woodcock-Johnson Psycho-Educational Battery - Letter-Word Identification subtest; WJ - AP = Woodcock-Johnson Psycho-Educational Battery - Applied Problems subtest; DCCS = Dimensional Change Card Sort Task

Results of piecewise regression

Threshold effects between teacher-child interactions and school readiness

The mean scores for each CLASS domain were used as cut points in the current study (Table 2). A cut-point of 6.59 was used for Emotional Support, 6.23 for Classroom Organization, and 3.19 for Instructional Support. This resulted in 59% of the children (N = 490) in higher-quality classrooms according to the Emotional Support threshold, 55% of the children (N = 462) in higher-quality classrooms according to the Classroom Organization threshold, and 45% of the children (N = 374) in higher-quality classrooms according to the Instructional Support threshold.

The results from the piecewise regression that tested whether the relationships between CLASS and child school readiness were stronger in above cut-points classrooms rather than below cut-points classrooms are shown in Table 4. A random intercept model that includes children's fall scores, age, language status, and gender as covariates was tested. The bolded numbers in Table 4 indicate significantly different coefficients for low and higher teacher-child interactions thresholds. As shown in Table 4, children demonstrated higher literacy skills, and math skills when Classroom Organization was above 6.23, compared to children who were in classrooms that received scores lower than 6.23. That is, after accounting for pre-test and covariates, higher-quality Classroom Organization predicted higher literacy skills (β = 4.60, p <.01), and math skills (β = 4.31, p <.05), but not in lower-quality classrooms. In addition, children demonstrated higher math skills when Instructional Support was above 3.19, compared to children who were in classrooms that received Instructional Support domain scores lower than 3.19. That is, after accounting for pre-test and covariates, higher-quality Instructional Support predicted higher math skills (β = 3.52, p <.05), but not in lower-quality classrooms. However, no significant evidence emerged indicating a quality threshold for Emotional Support and any of the school readiness outcomes.

Table 4

Results of Piecewise Regression for School Readiness

	Emotional Support						Classroom Organization						Instructional Support					
Cut point	6.59						6.23						3.19					
	Low (41%)			High (59%)			Low (45%)			High (55%)			Low (55%)			High (45%)		
	coeff	*p*	(SE)	coeff	*p*	(SE)	coeff	*p*	(SE)	coeff	*p*	(SE)	coeff	*p*	(SE)	coeff	*p*	(SE)
PPVT	-0.25		(2.18)	2.61		(4.44)	1.85		(1.61)	3.99		(2.52)	-1.86		(6.00)	-0.98		(1.96)
WJ - Letter word	0.48		(1.90)	3.55		(3.85)	**-1.71**		**(1.42)**	**4.60**	******	**(2.23)**	-1.11		(1.45)	1.75		(1.71)
WJ - applied problem	0.20		(1.90)	6.26		(3.83)	**-1.50**		**(1.46)**	**4.31**	*****	**(2.29)**	**-0.44**		**(1.47)**	**3.52**	*****	**(1.73)**
Peg Tapping	0.27		(0.96)	1.66		(1.92)	-0.04		(0.74)	0.55		(1.15)	0.31		(0.74)	0.18		(0.86)
DCCS	0.56		(1.06)	2.51		(2.13)	0.15		(0.81)	1.17		(1.25)	0.29		(0.79)	1.17		(0.93)

Note: *N* = 834 students within 82 classrooms. PPVT = Peabody Picture Vocabulary Test; WJ - Letter word = Woodcock-Johnson Psycho-Educational Battery, Letter-Word Identification subtest; WJ - AP = Woodcock-Johnson Psycho-Educational Battery, Applied Problem subtest; DCCS = Dimensional Change Card Sort Task

*p < .05; **p <.01; ***p < .001.

Threshold effect among monolingual English-speaking and dual language learning children

The current study extended previous studies by examining whether the association between CLASS and children's school readiness differed between English-speaking and dual language learning children. As shown in Tables 5 to 7, there were no evidence indicating there were differences in the quality threshold effects for Emotional Support and any of the school readiness outcomes. However, there were different threshold effects between Classroom Organization and children's language status in executive function skills measured by DCCS (Table 6), and different threshold effects between Instructional Support and children's language status in executive function skills measured by DCCS (Table 7).

Table 5

Multilevel Model Results of CLASS-Emotional Support on Children's School Readiness Moderate by Children's Language Status

	PPVT			WJ-Letter Word			WJ - Applie Problem			Peg Tapping			DCCS		
Fixed Effects	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*
Intercept	46.18	(24.13)		55.03	(20.98)	**	53.59	(21.39)	*	6.06	(11.17)		19.65	(12.28)	***
Fall score	0.73	(0.02)	***	0.82	(0.02)	***	0.66	(0.02)	***	0.51	(0.03)	***	0.53	(0.03)	**
Fall Age	1.48	(0.66)	*	-2.36	(0.58)	***	-2.91	(0.60)	***	1.87	(0.36)	***	1.06	(0.37)	
Female	0.24	(0.64)		0.29	(0.56)		-0.28	(0.58)		0.46	(0.32)		0.57	(0.34)	
CLASS_ES	-3.97	(3.83)		-4.33	(3.32)		-0.85	(3.38)		-1.51	(1.78)		-2.86	(1.96)	
English	-29.16	(26.33)		-41.29	(23.03)		-10.05	(23.71)		14.86	(12.76)		-28.29	(13.79)	*
CLASS_ES_HIGH	-49.52	(50.07)		-48.99	(43.55)		-69.50	(44.42)		14.17	(23.45)		-35.61	(25.69)	
CLASS_ES*English	4.85	(4.22)		6.49	(3.69)		1.53	(3.80)		2.40	(2.04)		4.61	(2.21)	*
CLASS_ES*CLASS_ES_HIGH	7.54	(7.49)		7.87	(6.52)		10.66	(6.65)		2.28	(3.51)		5.54	(3.84)	
English*CLASS_ES_HIGH	45.98	(55.07)		36.74	(48.14)		40.03	(49.74)		5.17	(26.97)		36.42	(28.96)	
CLASS_ES*English*CLASS_ES_HIGH	-6.82	(8.24)		-6.08	(7.20)		-6.09	(7.44)		-1.06	(4.03)		-5.73	(4.33)	
Random Effects	*Var*			*Var*			*Var*			*Var*			*Var*		
Intercept															
Classroom	4.69			3.21			2.73			0.34			0.77		
Residual	82.23			63.72			69.15			21.25			23.76		
Model Information															
Deviance (-2LL)	6081			5864.9			5927.1			4928.2			5031.9		
AIC	6107			5890.9			5953.1			4954.2			5057.9		
BIC	6168.4			5952.3			6014.5			5015.7			5119.4		

Note: N = 834 students within 82 classrooms. PPVT = Peabody Picture Vocabulary Test; DCCS = Dimensional Change Card Sort Task; CLASS-ES = Classroom Assessment Scoring System Emotional Support subscale ; CLASS_ES_HIGH = CLASS ES score above threshold (Mean = 6.59)
*p < .05; **p <.01; ***p < .001.

Table 6

Multilevel Model Results of CLASS-Classroom Organization on Children's School Readiness Moderate by Children's Language Status

	PPVT			WJ-Letter Word			WJ - Applie Problem			Peg Tapping			DCCS		
Fixed Effects	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff (SE)*		*p*
Intercept	-5.93	(18.26)		48.04	(16.45)	**	16.60	(16.49)		-4.11	(8.96)	***	9.12	(9.69)	***
Fall score	0.73	(0.02)	***	0.82	(0.02)	***	0.66	(0.02)	***	0.52	(0.03)	***	0.53	(0.03)	***
Fall Age	1.42	(0.65)	*	-2.40	(0.58)	***	-2.85	(0.59)	***	1.86	(0.36)		1.03	(0.37)	
Female	0.18	(0.63)		0.33	(0.56)		-0.34	(0.57)		0.48	(0.32)		0.58	(0.34)	
CLASS_CO	4.83	(3.10)		-3.22	(2.78)		5.52	(2.80)	*	0.06	(1.52)		-1.17	(1.65)	
English	21.91	(19.67)		-11.71	(17.52)		51.16	(17.88)	**	0.97	(9.79)		-9.85	(10.51)	
CLASS_CO_HIGH	-21.01	(27.19)		-45.23	(24.49)		-26.28	(24.56)		0.53	(13.28)		-34.09	(14.45)	*
CLASS_CO*English	-3.78	(3.41)		1.76	(3.04)		-8.98	(3.10)	**	-0.05	(1.70)		1.67	(1.82)	
CLASS_CO*CLASS_CO_HIGH	2.33	(4.37)		7.38	(3.93)		3.63	(3.95)		0.12	(2.13)		5.28	(2.32)	*
English*CLASS_CO_HIGH	9.99	(30.67)		7.07	(27.27)		-4.92	(27.87)		-4.85	(15.28)		38.14	(16.37)	*
CLASS_CO*English*CLASS_CO_HIGH	-0.37	(4.92)		-1.22	(4.38)		1.85	(4.47)		0.49	(2.45)		-5.77	(2.63)	*
Random Effects	*Var*			*Var*			*Var*			*Var*			*Var*		
Intercept															
Classroom	2.89			3.036			1.95			0.30			0.71		
Residual	81.94			63.695			68.63			21.23			23.61		
Model Information															
Deviance (-2LL)	6066.1			5863.1			5914			4926.0			5025.1		
AIC	6092.1			5889.1			5940.0			4952.0			5051.1		
BIC	6153.6			5950.5			6001.5			5013.4			5112.6		

Note: N = 834 students within 82 classrooms. PPVT = Peabody Picture Vocabulary Test; DCCS = Dimensional Change Card Sort Task; CLASS-CO = Classroom Assessment Scoring System Classroom Organization subscale ; CLASS_CO_HIGH = CLASS CO score above threshold (Mean = 6.23)
*p < .05; **p <.01; ***p < .001.

Table 7

Multilevel Model Results of CLASS-Instructional Support on Children's School Readiness Moderate by Children's Language Status

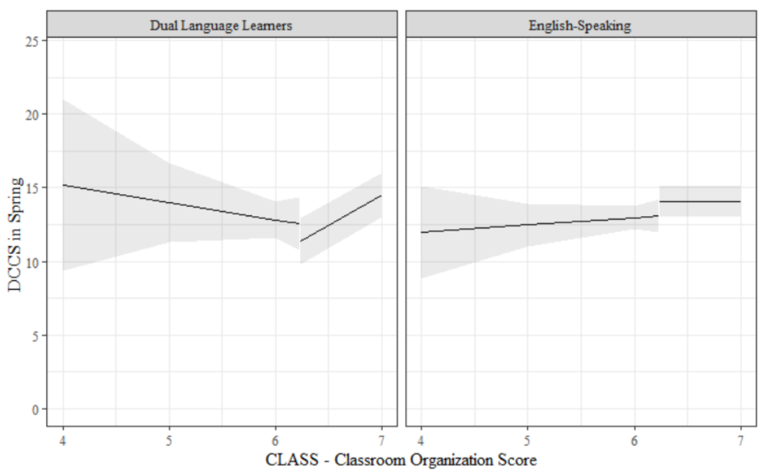
	PPVT			WJ-Letter Word			WJ - Applie Problem			Peg Tapping			DCCS		
Fixed Effects	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*	*coeff*	*(SE)*	*p*
Intercept	19.63	(5.81)	***	30.45	(7.53)	***	41.95	(7.45)	***	-7.91	(3.84)	*	7.45	(4.12)	***
Fall score	0.73	(0.02)	***	0.82	(0.02)	***	0.66	(0.02)	***	0.52	(0.03)	***	0.53	(0.03)	**
Fall Age	1.62	(0.66)	*	-2.30	(0.58)	***	-2.77	(0.60)	***	1.81	(0.36)	***	1.17	(0.37)	
Female	0.21	(0.64)		0.30	(0.56)		-0.40	(0.58)		0.50	(0.32)		0.54	(0.34)	
CLASS_IS	-0.02	(1.80)		-0.55	(2.54)		2.42	(2.59)		1.87	(1.38)		-2.32	(1.48)	
English	2.24	(2.97)		0.65	(7.32)		9.93	(7.52)		5.46	(4.11)		-8.79	(4.37)	*
CLASS_IS_HIGH	0.96	(1.51)		-8.67	(8.82)		-17.34	(8.90)		7.00	(4.77)		-12.62	(5.11)	*
CLASS_IS*English	0.04	(0.89)		-0.90	(2.80)		-3.89	(2.88)		-2.11	(1.58)		3.6	(1.67)	*
CLASS_IS*CLASS_IS_HIGH	0.72	(1.61)		2.51	(2.90)		3.84	(2.96)		-2.27	(1.57)		4.12	(1.68)	*
English*CLASS_IS_HIGH				0.61	(9.96)		7.19	(10.21)		-9.12	(5.57)		12.79	(5.91)	*
CLASS_IS*English*CLASS_IS_HIGH				0.42	(3.26)		-0.63	(3.34)		2.87	(1.83)		-4.44	(1.94)	*
Random Effects	*Var*			*Var*			*Var*			*Var*			*Var*		
Intercept															
Classroom	4.37			3.08			3.01			0.36			0.60		
Residual	82.60			64.01			68.19			21.24			23.70		
Model Information															
Deviance (-2LL)	6082.7			5867.4			5918			4928.3			50254		
AIC	6104.7			5893.4			5944			4954.3			5051.4		
BIC	6156.7			5954.9			6005.4			5015.7			5112.8		

Note: N = 834 students within 82 classrooms. PPVT = Peabody Picture Vocabulary Test; DCCS = Dimensional Change Card Sort Task; CLASS-IS = Classroom Assessment Scoring System Instructional Support subscale ; CLASS_IS_HIGH = CLASS IS score above threshold (Mean = 3.19)
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

To understand the nature of the threshold effects on the interaction between Classroom Organization and children’s language status on the DCCS, the predicted value of children’s DCCS scores were plotted. As shown in Figure 1, the relationships between Classroom Organization and DCCS differed between English-speaking and dual language learning children. For dual language learning children, when children were in classrooms that scored lower than 6.23, there was a negative relationship between Classroom Organization and DCCS. Accordingly, for every one-point score increase in Classroom Organization, children’s Spring DCCS scores were predicted to decrease by 1.17 points, holding all else constant. In contrast, when children were in a classrooms scored higher than the threshold (≥ 6.23), there was a positive relationship between Classroom Organization and DCCS. Accordingly, for every one-point score increase in Classroom Organization, children’s Spring DCCS scores were predicted to increase by 4.1 points, holding all else constant. On the other hand, for English-speaking children, there were positive relationships between Classroom Organization and DCCS below and above the thresholds. Specifically, for children who were in classrooms that received scores lower than the threshold (< 6.23), for every one-point score increase in Classroom Organization, children's Spring DCCS scores were predicted to increase by 0.49 points, holding all else constant. For children who were in classrooms that scoring higher than the threshold (≥ 6.23), for every one-point score increase in Classroom Organization, children's Spring DCCS scores were predicted to increase by 0.002 points, holding all else constant.

Figure 1

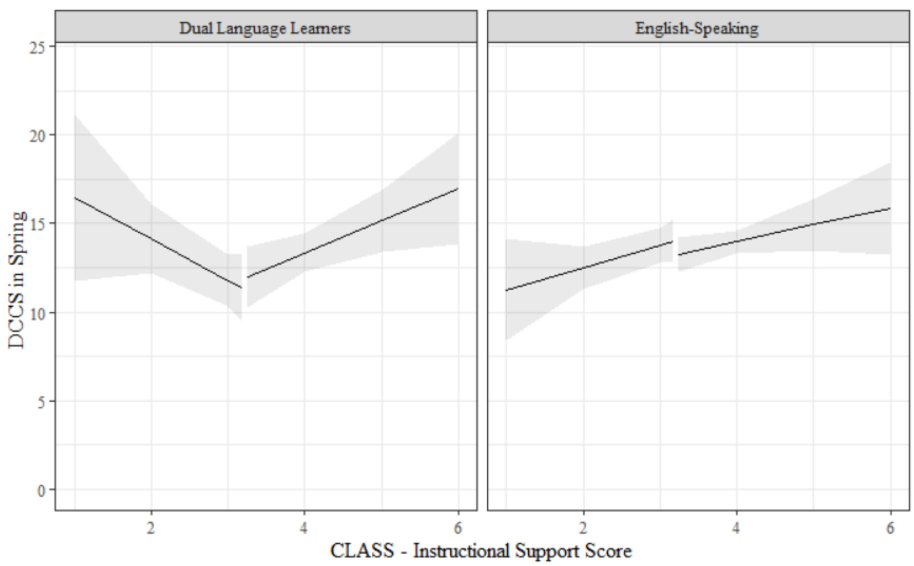
Interaction between Language Status and Classroom Organization on DCCS among Dual Language Learning Children and Monolingual English-speaking Children



Similarly, to understand the nature of the threshold effect of the interaction between Instructional Support and children's language status on DCCS, the predicted value of children's DCCS scores were plotted. As shown in Figure 2, the relationships between Instructional Support and DCCS differed between English-speaking and dual language learning children. For dual language learning children, when children were in classrooms scored lower than 3.19, there was a negative relationship between Instructional Support and DCCS. Accordingly, for every one-point score increase in Instructional Support, children's Spring DCCS scores were predicted to decrease by 2.32 points, holding all else constant. In contrast, when children were in classrooms scored higher than the threshold (≥ 3.19), there was a positive relationship between Instructional Support and DCCS. Accordingly, for every one-point score increase in Instructional Support, children's Spring DCCS scores were predicted to increase by 1.8 points, holding all else constant. On the other hand, for English-speaking children, there were positive relationships between Instructional Support and DCCS scores below and above the thresholds. For children who were in classrooms scored lower than the threshold (< 3.19), for every one-point score increase in Instructional Support, children's Spring DCCS scores were predicted to increase by 1.28 points, holding all else constant. For children who were in classrooms that scored higher than the threshold (≥ 3.19), for every one-point score increase in Instructional Support, children's Spring DCCS scores were predicted to increase by 0.96 points, holding all else constant.

Figure 2

Interaction between Language Status and Instructional Support on DCCS among Dual Language Learning Children and Monolingual English-speaking Children



Discussion

The purpose of the study was to examine the threshold effects between teacher-child interactions and children's school readiness, including receptive language, literacy skills, math skills and executive function. Further, the current study extended previous studies by examining whether the threshold effects differed between monolingual English-speaking children and dual language learning children. While previous studies used a cut-point of 5 or 6 for Emotional Support and Classroom Organization, and 3 for Instructional Support, the current study used a mean score of 6.59 and 6.23 for Emotional Support and Classroom Organization, respectively, and 3.19 for Instructional Support due to the relatively high CLASS domain scores observed in the current study. In general, there were threshold effects for Classroom Organization and Instructional Support on children 's letter word knowledge and literacy skills, and math skills across children. In addition, there were different threshold effects between Classroom Organization and children's language status, as well as Instructional Support and children's language status on executive function as measured by the DCCS.

The results of the current study are consistent with previous findings that there was no difference on any of the school readiness in classrooms scoring lower or higher in the Emotional Support classrooms domain (Burchinal et al., 2010; Burchinal et al., 2014; Guerrero-Rosada et al., 2021). However, contrary to other studies that did not find threshold effects between Classroom Organization and children's school readiness (Burchinal et al., 2010; Burchinal et al., 2014; Guerrero-Rosada et al., 2021), the current study found that higher Classroom Organization was more strongly correlated with children's literacy and math skills compared to lower-quality classrooms. The results are consistent with previous study indicating that children demonstrated higher literacy skills in classrooms where teachers consistently provided clear behavioral expectations, manage instructional time and maximize students' learning (Hatfield et al., 2016). The discrepancy in results between the current study and other studies could be due to the different cut-points used across studies. In the current study, a relatively higher cut-point of 6.23 was used for Classroom Organization, while other studies finding null relationships used a cut-point of 5 in their studies. It could be that higher levels of Classroom Organization are needed to have an impact on children's literacy and math skills. Specifically, teachers in classrooms need to consistently and effectively enforce behavioral expectations, proactively monitor the classroom, and facilitate students' engagement in activities to expand children's involvement in order to promote children's literacy and math skills. Teacher with high-quality Classroom Organization, are better at managing instructional time and maximizing children's engagement and may provide children with more opportunities to practice and use language (Reily et al., 2019). Additionally, doing mathematics requires children to concentrate on manipulating and calculating, a classroom that is well-organized may provide children with environment to better focus their attention and thereby enhance their math skills (Fuhs et al., 2015; McClelland & Cameron, 2019).

While many previous studies did not find threshold effects between Instructional Support and children's school readiness (Burchinal et al., 2014; Guerrero-Rosada et al., 2021; Hatfield et al., 2016), findings of the current study showed that the association between Instructional Support and math skills was stronger when in higher-quality classroom, compared to lower-quality classrooms. These findings are in line with Burchinal et al., (2010)'s study indicating the magnitude of the association between teacher-child interactions and school readiness were stronger in classrooms with higher Instructional Support. As noted earlier, the difference between results of the current study and in prior studies could be due to the different thresholds used for the studies. The current study used a cut-point of 3.19 for Instructional Support, whereas studies finding null relationships used a cut-point of 3 for Instructional Support. It is likely that when Instructional Support is relatively low, teachers rarely engage in activities that promote higher order thinking and cognition, rarely provide feedback that expands learning, and rarely use effective language stimulation and facilitation (Burchinal et al., 2010; Hatfield et al., 2016). As the average of Instructional Support tends to be relatively low across studies, even a small difference in scores would possibly have an impact on children's outcomes. In addition, it is possible that the domains of CLASS may be too general to influence children's school readiness. Previous studies have suggested that it is important to identify specific course contents that may be related specific areas of children's school readiness (Burchinal et al., 2014). In addition, previous studies have suggested that it is possible that teacher-child interactions observed by the CLASS do not capture behaviors or interactions that are more predictive of children's school readiness (Guerrero-Rosada et al., 2021), therefore resulting in the null relationship between teacher-child interactions and school readiness. Further studies should consider choosing different thresholds to understand how different cut-points may affect the association between teacher-child interactions and children's school readiness.

Threshold effect among monolingual English-speaking and dual language learning children

The present study found no evidence indicating differences on threshold effects for Emotional Support and any of the school readiness among monolingual English-speaking and dual language learning children. However, there were differing threshold effects for monolingual and DLLs in the association between Classroom Organization and executive function, as well as Instructional Support and executive function. For dual language learning children, higher Classroom Organization and Instructional Support scores above the thresholds were related to larger increases in executive function, while there were negative relationships between teacher-child interactions and executive function in lower-quality classrooms. This is in line with Hatfield et al. (2016)'s findings that children demonstrated higher executive function when Classroom Organization is higher than 6. On the other hand, for monolingual children, Classroom Organization and Instructional Support were related to increases in executive function regardless whether children were in classrooms above or below the threshold. There are some possibilities for the different patterns across monolingual and dual language learning children.

First, it is likely that the effect of Classroom Organization matters more for dual language learning children compared to monolingual children. According to Guerrero-Rosada et al., (2021), teacher-child interactions may be more important for children who are more disadvantaged and have lower skills when they enter school compared to their peers. Dual language learning children may enter the school with lower levels of executive function and other school readiness skills, as well as having language deficits compared to monolingual English-speaking children. DLLs may function better in classrooms that are well-managed and provide many opportunities for children to be involved and engaged in learning activities. Given such well-organized and predictable schedule, DLLs in these kinds of learning environments may be better able to follow the schedule and rule, and routinely practice regulating skills that enhance their executive function skills. However, it should be noted that though the dual language children included in the current study tended to demonstrate lower school readiness skills, this is not always the case. There are dual language children who have high language proficiency and perform well across different academic domains (Langeloo et al., 2019). Further study should take these DLLs into account to gain a more thorough understanding of the association between teacher-child interactions and dual language learners.

Second, classrooms with high quality Classroom Organization can help dual language learning children focus their attention on instruction and necessary tasks. In comparison to monolingual children, dual language learning children may need to exhibit more attention and efforts on teacher's instructions and class rules due to their language disadvantage. In a classroom where clear expectations and structure are provided, dual language children may feel less stress and can devote more attention to the classroom activities, allowing them to practice regulating skills, thereby strengthening their executive function development (Vandenbroucke et al., 2018). In addition, when a classroom is well-manageed with a predictable schedule, it offers external help for DLLs to easily explore the environment and engage in learning to practice executive function skills in a more organized environment (Choi et al., 2016). In contrast, when a classroom is not well-organized enough, dual language children may need to devote more attention in understanding teacher's instructions and classroom routines, thereby resulting in a negative relationship between Classroom Organization and their executive function development.

The present study's results also found a positive relationship between Instructional Support and executive function among dual language learning children when in classrooms at or above the threshold cut point for Instructional Support, while the relationship was negative in classrooms below the cut-point. In contrast, results indicated a positive relationship between Instructional Support and executive function among monolingual children when in classrooms both above and below the cut point for Instructional Support. It is likely that Instructional Support is more important for dual language learners compared to monolingual children. Specifically, previous studies have indicated that DLLs may have less exposure and chance to practice English at home compared to monolingual children (Reilly et al., 2019). Thus in classroom where teachers are consistently encouraging children's higher-order thinking skills, providing feedback to expand participation, and stimulating and facilitating children's language, children actively engage in a variety of experiences that facilitate their learning, which is known to be associated with children's executive function develpment (Fay-Stammbach et al., 2014). In contrast, monolingual children, have a relatively higher level of executive function when they start school compared to dual language learning children, and it is possible that the effects of teacher-child interactions on their regulating skills become limited. Therefore, the association between teacher-child interactions and executive function below and above the threshold remained similar for monolingual children. In conclusion, the results concerning executive function and Classroom Organization, as well as executive function and Instructional Support suggest that attention should be paid to classrooms that received lower range of Classroom Organization and Instructional Support, especially when there are dual language learning children in the classrooms.

The current study found no threshold evidence of an association between language status and CLASS on children's executive function measured by Peg Tapping. The result is similar to previous studies finding no relationship between teacher-child interactions and Peg Tapping (Guerrero-Rosada et al., 2021). It is suggested that the DCCS is used to measure children's coordination of working memory and inhibition, as well as overall executive function skills, while the Peg Tapping is commonly used to measure only inhibition that requires withholding or restraining a response (Garon et al., 2008). It is possible that teacher-child interactions may affect different domains of executive function, which could not be captured by the Peg Tapping test. On the other hand, it could be the teacher-child interactions observed by the CLASS only affect children's overall executive function but not children's inhibition skills. Accordingly, the current study could not disentangle whether the null relationship was due to a lack of sensitivity of the CLASS or due to the different component of executive function measured by different executive function measures (Guerrero-Rosada et al., 2021). Further study is needed to disentangle these issues.

Limitations and future directions

The current study has several limitations. The classrooms in the current study received relatively higher scores on CLASS, especially in the Emotional Support and Classroom Organization domains. It is possible that the study overestimated the effects of teacher-child interactions on children's school readiness. Second, although most classrooms included in the study used either the High Scope or the Creative Curriculum, the study failed to account for curricula in each class. It is possible that the curricula used in each classroom may have an influence on how teachers interact with children and on their school readiness (Buchinal et al., 2014). More information regarding the content of instruction and instructional practices is needed. Finally, as stated, the quality of teacher-child interactions was measured only by the CLASS, which may be too general to capture the intricacies of interactions between teachers and children. In addition, as there were dual language children in the study classrooms, the CLASS may not be culturally sensitive to capture the interactions between teachers and dual language children. Further, using the CLASS did not differentiate as to whether monolingual and dual language children were exposed to different level or patterns of teacher-child interactions (Langeloo et al., 2019). Further studies should consider coupling the CLASS with other observation tools that consider the cultural diversity of children to better reflect teacher-child interactions across cultures.

References

Bihler, L.-M., Agache, A., Schneller, K., Willard, J. A., & Leyendecker, B. (2018). Expressive Morphological Skills of Dual Language Learning and Monolingual German Children: Exploring Links to Duration of Preschool Attendance, Classroom Quality, and Classroom Composition. *Frontiers in Psychology*, *9*, 888. https://doi.org/10.3389/fpsyg.2018.00888

Burchinal, M., Field, S., López, M. L., Howes, C., & Pianta, R. (2012). Instruction in Spanish in pre-kindergarten classrooms and child outcomes for English language learners. *Early Childhood Research Quarterly*, *27*(2), 188-197. https://doi.org/10.1016/j.ecresq.2011.11.003

Burchinal, M., Vandergrift, N., Pianta, R., & Mashburn, A. (2010). Threshold analysis of association between child care quality and child outcomes for low-income children in pre-kindergarten programs. *Early Childhood Research Quarterly*, *25*(2), 166–176. https://doi.org/10.1016/j.ecresq.2009.10.004

Burchinal, M., Vernon-Feagans, L., Vitiello, V., & Greenberg, M. (2014). Thresholds in the association between child care quality and child outcomes in rural preschool children. *Early Childhood Research Quarterly*, *29*(1), 41–51. https://doi.org/10.1016/j.ecresq.2013.09.004

Cadima, J., Verschueren, K., Leal, T., & Guedes, C. (2016). Classroom Interactions, Dyadic Teacher–Child Relationships, and Self–Regulation in Socially Disadvantaged Young Children. *Journal of Abnormal Child Psychology*, *44*(1), 7–17. https://doi.org/10.1007/s10802-015-0060-5

Carr, R. C., Mokrova, I. L., Vernon-Feagans, L., & Burchinal, M. R. (2019). Cumulative classroom quality during pre-kindergarten and kindergarten and children's language, literacy, and mathematics skills. *Early Childhood Research Quarterly*, *47*, 218–228. https://doi.org/10.1016/j.ecresq.2018.12.010

Choi, J. Y., Castle, S., Williamson, A. C., Young, E., Worley, L., Long, M., & Horm, D. M. (2016). Teacher–Child Interactions and the Development of Executive Function in Preschool-Age Children Attending Head Start. *Early Education and Development*, *27*(6), 751–769. https://doi.org/10.1080/10409289.2016.1129864

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do". *Developmental Psychobiology*, *29*(4), 315–334. https://doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Downer, J. T., López, M. L., Grimm, K. J., Hamagami, A., Pianta, R. C., & Howes, C. (2012). Observations of teacher–child interactions in classrooms serving Latinos and dual language learners: Applicability of the Classroom Assessment Scoring System in diverse settings. *Early Childhood Research Quarterly*, *27*(1), 21-32. https://doi.org/10.1016/j.ecresq.2011.07.005

Duncan, R. J., McClelland, M. M., & Acock, A. C. (2017). Relations between executive function, behavioral regulation, and achievement: Moderation by family income. *Journal of Applied Developmental Psychology*, *49*, 21-30. https://doi.org/10.1016/j.appdev.2017.01.004

Dunn, L. M., & Dunn, D. M. (2007). PPVT-4: Peabody picture vocabulary test. Pearson Assessments.

Fay-Stammbach, T., Hawes, D. J., & Meredith, P. (2014). Parenting Influences on Executive Function in Early Childhood: A Review. *Child Development Perspectives*, *8*(4), 258–264. https://doi.org/10.1111/cdep.12095

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessments and teacher ratings. *Journal of Educational Psychology*, *107*(1), 207–221. https://doi.org/10.1037/a0037366

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Guerrero-Rosada, P., Weiland, C., McCormick, M., Hsueh, J., Sachs, J., Snow, C., & Maier, M. (2021). Null relations between CLASS scores and gains in children's language, math, and executive function skills: A replication and extension study. *Early Childhood Research Quarterly, 54*, 1-12. https://doi.org/10.1016/j.ecresq.2020.07.009

Hamre, B., Hatfield, B., Pianta, R., & Jamil, F. (2014). Evidence for general and domain-specific elements of teacher-child interactions: Associations with preschool children's development. *Child Development*, *85*(3), 1257–1274. https://doi.org/10.1111/cdev.12184

Hatfield, B. E., Burchinal, M. R., Pianta, R. C., & Sideris, J. (2016). Thresholds in the association between quality of teacher–child interactions and preschool children's school readiness skills. *Early Childhood Research Quarterly, 36*, 561–571. https://doi.org/10.1016/j.ecresq.2015.09.005

Hu, B. Y., Fan, X., Wu, Y., LoCasale-Crouch, J., & Song, Z. (2019). Contributions of Teacher–Child Interaction Quality to Chinese Children's Development in the Early Childhood

Years. *Early Education and Development*, *30*(2), 159-177. https://doi.org/10.1080/10409289.2018.1544809

Hu, B. Y., Fan, X., Wu, Y., LoCasale-Crouch, J., & Song, Z. (2020). Teacher–child interaction quality and Chinese children's academic and cognitive development: New perspectives from piecewise growth modeling. *Early Childhood Research Quarterly*, *51*, 242–255. https://doi.org/10.1016/j.ecresq.2019.10.003

Langeloo, A., Lara, M. M., Deunk, M. I., Klitzing, N. F., & Strijbos, J.-W. (2019). A Systematic Review of Teacher–Child Interactions With Multilingual Young Children: *Review of Educational Research*. https://doi.org/10.3102/0034654319855619

Leyva, D., Weiland, C., Barata, M., Yoshikawa, H., Snow, C., Treviño, E., & Rolla, A. (2015). Teacher-child interactions in Chile and their associations with prekindergarten outcomes. *Child Development*, *86*(3), 781–799. https://doi.org/10.1111/cdev.12342

Li, K., Zhang, P., Hu, B. Y., Burchinal, M. R., Fan, X., & Qin, J. (2019). Testing the 'thresholds' of preschool education quality on child outcomes in China. *Early Childhood Research Quarterly*, *47*, 445–456. https://doi.org/10.1016/j.ecresq.2018.08.003

Mashburn, A. J., Pianta, R. C., Hamre, B. K., Downer, J. T., Barbarin, O. A., Bryant, D., Burchinal, M., Early, D. M., & Howes, C. (2008). Measures of classroom quality in prekindergarten and children's development of academic, language, and social skills. *Child Development*, *79*(3), 732–749. https://doi.org/10.1111/j.1467-8624.2008.01154.x

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children's early academic lives. *Early Childhood Research Quarterly*, *46*, 142–151. https://doi.org/10.1016/j.ecresq.2018.03.014

McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00599

Meuwissen, A. S., & Englund, M. M. (2016). Executive function in at-risk children: Importance of father-figure support and mother parenting. *Journal of Applied Developmental Psychology*, *44*, 72–80. https://doi.org/10.1016/j.appdev.2016.04.002

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M., & Morrison, F. J. (2016). The development of self-regulation across early childhood. *Developmental Psychology*, *52*(11), 1744–1762. https://doi.org/10.1037/dev0000159

Nores, M., Barnett, W.S., Jung, K., Joseph, G. & Bachman, L. (2019). Year 4 report: Seattle Preschool Program evaluation. New Brunswick, NJ: National Institute for Early Education Research & Seattle, WA: Cultivate Learning

Pakarinen, E., Lerkkanen, M.-K., Poikkeus, A.-M., Kiuru, N., Siekkinen, M., Rasku-Puttonen, H., & Nurmi, J.-E. (2010). A Validation of the Classroom Assessment Scoring System in Finnish Kindergartens. *Early Education and Development*, *21*(1), 95–124. https://doi.org/10.1080/10409280902858764

Park, M., O'Toole, A., & Katsiaficas, C. (2017). Dual Language Learners: A National Demographic and Policy Profile. Fact Sheet. *Migration Policy Institute*. Retrieved from file:///C:/Users/arbo0/Downloads/DLL-FactSheet-US-FINAL%20(1).pdf

Pianta, R. C., La Paro, K. M., & Hamre, B. K. (2008). *Classroom Assessment Scoring System™ (CLASS™) Manual, Pre-K*. Baltimore, MD: Brookes Publishing.

Vandenbroucke, L., Spilt, J., Verschueren, K., Piccinin, C., & Baeyens, D. (2018). The Classroom as a Developmental Context for Cognitive Development: A Meta-Analysis on the Importance of Teacher–Student Interactions for Children's Executive Functions. *Review of Educational Research*, *88*(1), 125–164. https://doi.org/10.3102/0034654317743200

Vernon-Feagans, L., Mokrova, I. L., Carr, R. C., Garrett-Peters, P. T., & Burchinal, M. R. (2019). Cumulative years of classroom quality from kindergarten to third grade: Prediction to children's third grade literacy skills. *Early Childhood Research Quarterly*, *47*, 531–540. https://doi.org/10.1016/j.ecresq.2018.06.005

Von Suchodoletz, A., Fäsche, A., Gunzenhauser, C., & Hamre, B. K. (2014). A typical morning in preschool: Observations of teacher–child interactions in German preschools. *Early Childhood Research Quarterly*, *29*(4), 509–519. https://doi.org/10.1016/j.ecresq.2014.05.010

Weiland, C., Ulvestad, K., Sachs, J., & Yoshikawa, H. (2013). Associations between classroom quality and children's vocabulary and executive function skills in an urban public prekindergarten program. *Early Childhood Research Quarterly*, *28*(2), 199–209. https://doi.org/10.1016/j.ecresq.2012.12.002

White, L. J., Fernandez, V. A., & Greenfield, D. B. (2020). Assessing Classroom Quality for Latino Dual Language Learners in Head Start: DLL-Specific and General Teacher-Child Interaction Perspectives. *Early Education and Development*, 1-29. https://doi.org/10.1080/10409289.2019.1680785

Woodcock, R. W., McGrew, K. S., Mather, N., & Schrank, F. (2001). Woodcock-Johnson III NU tests of achievement. Rolling Meadows, IL: Riverside Publishing.

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*(1), 297. https://doi.org/10.1038/nprot.2006.46