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Teacher-Child Interaction and Cognitive Development in Rio de Janeiro Preschools

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ABSTRACT: Previous research has found that the quality of teacher-child interactions is considered one of the primary mechanisms to foster children's language, mathematics, socioemotional, and self-regulation development. The study describes the quality of teacher-child interactions measured with the Classroom Assessment Scoring System (CLASS) in 59 preschool classrooms in Rio de Janeiro public schools. It estimates the impact of classroom interactions on children's cognitive development. The data is a subsample of a longitudinal study that tracked children over two years in preschool and presents a probabilistic single-stage cluster sample (school as the primary sampling unit) from the Rio de Janeiro municipal public system with 2716 children assessed. Confirmatory factor analysis provides evidence to support three specific domains of teacher-child interactions in Brazil. Multilevel models estimated the relationship between teacher-child interactions and cognitive development with cross-sectional and value-added models. Results suggest that instructional support positively correlates with language and mathematics development, even after controlling for baseline measures. Implications for educational policy are discussed.

Keywords: *teacher-child interactions, CLASS, cognitive development, early childhood education*

Introduction

There is increasing pressure in society to improve the quality and equity of education. International longitudinal studies have confirmed that, as a general rule, children who have had the opportunity to attend good quality early childhood-care programs have shown greater development of cognitive and socioemotional skills in the short and medium term, during their school trajectories (Peisner-Feinberg et al., 2001; Sammons et al., 2008; Sylva et al., 2010; Tymms et al., 2009, NICHD, 2003). In most cases, those studies focused on process quality of early childhood education [ECE] and indicate that the impact benefits more disadvantaged or at-risk children and can be an essential policy to reduce education and social inequality.

A large body of research has found that child and teacher interactions are considered one of the primary mechanisms to foster children's language, mathematics, socioemotional, self-regulation development and play an essential role in the curriculum (Downer et al., 2010). The studies provide insights on how children learn, as well as helps to define what is effective teaching and which aspects of interactions best supports development (Kane & Staiger, 2012 [Measures of Effective Teaching – MET]; National Institute of Child Health and Human Development [NICHD] Early Child Care Research Network [ECCRN], 2003; Pianta et al., 2005).

One of the most commonly used approaches is Teaching Through Interactions - framework (Hamre et al., 2013). Theories on the importance of emotional support, classroom management, organization, and instructional support to children's learning and development support this framework. The Teaching Through Interactions - framework has been vastly measured using the Classroom Assessment Scoring System (CLASS) (Pianta et al., 2008), first developed for a large-scale study in the United States. It has been improved and used in many other countries. In Latin America, the CLASS has supported the evaluation of interactions in ECE in countries such as Mexico, Ecuador, Costa Rica, Chile, and now, Brazil.

The paper presents descriptive data for the quality of teacher-child interactions in 60 preschool classrooms in Rio de Janeiro public schools and estimates the impact of classroom interactions on children's cognitive development. The analysis exam if there is evidence supporting three distinct domains of teacher-child interactions in Brazil (confirmatory factor analysis) and whether these domains predict the end of preschool language and mathematic development (predictive validity).

The data is a subsample of a longitudinal study that tracked children over two years (2017–2018) in preschool. It presents a probabilistic single-stage cluster sample (school as the primary sampling unit) from Rio de Janeiro municipal public system with 2716

children assessed (Bartholo, Koslinski, Costa, & Barcellos, 2020; Koslinski et al., 2019). A total of 60 classrooms were randomly selected and tape-recorded following the guidelines indicated in the CLASS manual (Pianta et al., 2008) and later coded by CLASS certified observers. Language and early mathematics development were measured using PIPS (Performance Indicator for Primary Schools – PIPS), an adaptive test with a reliable measure at the individual level (Bartholo, Koslinski, Costa, Tymms et al., 2020; Tymms, 1999; Tymms et al., 2004).

There is extensive literature analyzing the relationship between process quality and children's cognitive development in early childhood education, especially using CLASS (Classroom Assessment Scoring System) (Pianta et al., 2008; Pianta & Hamre, 2009). Several studies have used the CLASS in Latin America (Araujo et al., 2016; Cruz-Aguayo et al. 2019; Francisco et al., 2005; Hanno et al., 2020; Jensen et al., 2020; Levya et al., 2015,). However, no previous large-scale studies used CLASS domains as predictors of cognitive development in Brazil. This paper extends the literature on the quality of teacher-child interactions. It adds to previous research that used CLASS by focusing on how this framework fits in settings where ECE provision is recently expanding and gaining space in the educational agenda.

Interactions framework in early childhood education and child outcomes

The environment that closely surrounds children, including proximal systems such as family and school, strongly influences their learning and development processes. Therefore, numerous studies that aim to understand the mechanisms through which ECE classrooms impact children's language, cognitive, socio-emotional, and self-regulation development have used measures of the quality of interactions.

One of the most commonly used approaches is Teaching Through Interactions [TTI] - framework (Hamre et al., 2013). Theories on the importance of emotional support, classroom management, and organization, and instructional support to children's learning and development support this framework. The attachment and self-determination theories underpin teachers' ability to support young children emotionally. According to these theories, predictable and safe environments that assist children in being autonomous and feeling competent and sociable promote learning and motivation. In another domain, how teachers self-regulate and manage time and behavior in the classroom may help children organize their behavior and attention. In addition, evidence of teachers' instructional support is related to research on how: usable knowledge is built, language development can be scaffolded, new information relates to previous knowledge,

and feedback is essential to intervene in cases of frustration, demotivation, and promotion of higher-order cognitive processes (Hamre et al., 2014). The CLASS's three-domain structure encompasses Emotional Support, Classroom Organization, and Instructional Support. These are broken down into dimensions and indicators, enabling a more detailed understanding of how teachers' practices and interactions vary in specific aspects (Hamre et al., 2013).

The Teaching Through Interactions framework has vastly used the CLASS (Pianta et al., 2008). As a result, a growing number of studies have tried to observe the associations between process aspects measured using the CLASS protocol and preschoolers' outcomes. For example, Perlman et al. (2016) systematic review and meta-analysis considered published studies that conformed with the following criteria: (i) exposure to programs (as opposed to home-based childcare); (ii) focus on preschool-age children (age ranging from 30–72 months); (iii) focus on the relationship between CLASS and children's cognitive, academic, social-emotional, health, or motor outcomes; (iv) cross-sectional and longitudinal designs; (v) written in English. The systematic review found 35 studies, 31 with longitudinal and 4 with cross-sectional designs, all focusing on the US context, and the meta-analysis only considered studies focusing on linear relationships.

Perlman et al. (2016) systematic review and meta-analyses found a small number of statistically significant associations between CLASS domains and child's outcomes (cognitive, language, and socio-emotional outcomes). Moreover, the review did not find a clear pattern of stronger statistically significant association between the different CLASS domains or dimensions and specific child outcomes (e.g., the association between emotional support and social-emotional development or language modeling and vocabulary). When studies added covariates to the models, the authors observed that fewer CLASS domains showed statistically significant association with child outcomes. Nonetheless, it is interesting to notice that studies with larger samples (for example, more than 600 classrooms) reported statistically significant associations to a greater number of outcomes. Therefore, apart from only considering the statistical significance, one should also look at the pattern of correlations (positive or negative) and confidence interval of the coefficients to better understand the relationship between teacher-child interactions and child development.

Finally, Perlman et al. (2016) indicate some drawbacks of the studies that might have hindered the identification of the association between process quality and children's outcomes: selection biases and heterogeneity of the studies (variability in the use of outcomes and covariates and reported statistics). Finally, although instructional support was more strongly associated with the outcomes, it presented the lowest scores compared to the other two CLASS domains, which might explain the small effect sizes reported by the studies.

The authors defend that identifying the minimum level of quality might be necessary to observe the desired impact on children, which are not captured by statistical models that assume linear relationships. For example, the study carried out by Burchinal et al. (2010) identified thresholds in quality of interactions that make a difference in children's outcomes and observed that emotional climate was more positively associated with social competence and children' behavior and instructional climate was more associated to language, reading and math skills in higher quality classrooms.

In a more recent meta-analysis, Hong et al. (2019) have observed the association between structure and process quality using data from six large childcare studies. The meta-analysis has found a small, positive, and statistically significant relationship between instructional support and classroom organization continuous measures and early literacy outcomes. However, the gains were small: effect size of 0.06 and 0.05, respectively. Although only the parameter estimated for early literacy was statistically significant, the association between the instructional support and other outcome variables (language, math, and social skills) was consistently positive. The analysis did not find consistent results using the continuous measures for the other CLASS domains. The emotional and instructional support measures were positively associated with pre-literacy and language when using categorized ratings. Again, the effect sizes reported were small, ranging from 0.05 to 0.08.

The studies discussed above show that most results are modest and restricted to the USA context. Further studies in different contexts are needed to understand this relationship and improve quality measures (Perlman et al., 2016; Burchinal, 2017). Since 2015, we have observed a growing number of publications reporting the use of CLASS to measure process quality in preschool and kindergarten classrooms in Latin American countries (Araujo et al., 2016; Cruz-Aguayo et al., 2019; Francisco et al., 2005; Hanno et al., 2020; Jensen et al., 2020; Levya et al., 2015). The studies conducted in Chile, Peru, Ecuador, Trinidad and Tobago, Mexico, and Costa Rica focused on children between three and six -years of age. Most of them have used Hamre et al. (2013) conceptual framework with three key domains of teacher-child interactions (emotional support, classroom organization, instructional support).

TABLE 1 Mean scores for CLASS domains found in Latin American studies focusing preschool and kindergarten[1]

STUDY	*EMOTIONAL SUPPORT*	*CLASSROOM ORGANIZATION*	*INSTRUCTIONAL SUPPORT*
Chile (preschool) Levya et al. (2015)	4.65	4.29	1.75
Peru (preschool) Hanno et al. (2020)	5.28	4.78	2.07
Trinidad and Tobago (preschool) Cruz-Aguayo (2019)	4.81	4.37	1.43
Ecuador (kindergarten) Cruz-Aguayo (2019)	4.07	4.79	1.15
Costa Rica (kindergarten) Francisco et al. (2005)	5.4	4.9	2.5

Note. [1] Jensen et al. (2020) focused on kindergarten and first-year classrooms in Mexico, but they do not report the scores separately. All studies measured more than fifty classrooms, except Francisco et al. (2005), only nine classrooms in Costa Rica.

The studies focusing on preschool settings in Chile, Peru, and Trinidad and Tobago have found slightly lower scores for the three domains when compared to those found in the US. The scores for emotional support ranged from 4.07 to 5.28, classroom organization from 4.29 up to 4.79, and instructional support from 1.43 up to 2.07. Those studies have observed middle range average scores for the first two domains and low range scores for the instructional support domain, following the same pattern observed in the USA and other studies conducted in European contexts (Hong et al., 2019; Cadima et al., 2018; Kohl et al., 2019; Suchodoletz et al., 2014).

However, only two of the Latin American studies would fit the criteria described by the meta-analysis conducted by Perlman et al. (2016): one study developed in Chile (Leyva et al., 2015) and another one in Peru (Hanno et al., 2020). Both studies use confirmatory factor analysis (CFA) to test for CLASS construct validity in their specific contexts, apart from pursuing the aim of observing CLASS domains' predictive validity. In both cases, a three-factor solution seemed to be a better fit than a two-factor or single-factor model, even though the dimensions presented lower loadings if compared to those found in the USA context. Despite the similarities, these two studies use different research designs.

Leyva et al. (2015) present more robust evidence, as the study had a longitudinal design, a random sample of 64 schools, 91 classrooms, and 1868 children and considered the association of CLASS domains to various pre-schoolers outcomes such as language, early literacy, and numeracy and executive function measures. However, the study does not include socioeconomic status (SES) measures as control variables. The research focused on public schools located in Santiago. The authors reported the results of multilevel linear

regression models, emphasizing the positive and statistically significant relationship between instructional support and early writing and executive function, with small effect sizes of 0.09 and 0.06, respectively. The results also indicate a positive quadratic relationship between classroom organization and gains in language, early writing, and early numeracy. Spline regression results indicate a positive and statistically significant association of this domain with language, early writing, and early numeracy within the higher range of the scale. The relationships observed for emotional support were not consistent. Within the higher range, the domain was positively associated with early writing, and at its lower range, it was negatively associated with executive function. Again, the effect sizes found were small, ranging from -0.03 to 0.10.

The study conducted in Lima, Peru, had a cross-sectional design involving 1536 children enrolled in 128 classrooms in 64 public ECE centers and only considered a single language outcome. Hanno et al. (2020) did not find linear associations between class domains and children's language scores, and the results point to different nonlinear associations as those found by Levya et al. (2015). The study found a negative quadratic association between instructional support and children´s language scores. The spline regression indicated a positive association between this CLASS domain at the lower end of the distribution (scores below two). Although the spline regression for classroom organization did not find significant parameters in Peru, the results indicate a tendency similar to the one observed in Chile: a stronger positive association with children's language score at the higher levels of this domain (scores equal or greater to five).

A study conducted in Ecuador, with a slightly different focus, also observed process quality, measured by CLASS, and children's language, math, and executive function outcomes (Araujo et al., 2016). The focus of the study was kindergarten, the first year of formal education in Ecuador, attended by children age 5. It was a large-scale study, with a longitudinal design, including a random sample of 204 classrooms and around 13,000 children. Another difference from the studies conducted in Chile and Peru was that analyses used an overall CLASS score (average of the ten dimensions). The results reported by Araujo et al. (2016) indicate that one standard deviation increase of CLASS overall score was associated with an increase of 0.11 standard deviations in language and math test scores and of 0.07 in executive function measures.

However, these studies present limitations that hinder future comparisons with data from Rio de Janeiro, Brazil. The studies have different research designs and use different covariates and outcome variables. Moreover, except for Araujo et al. (2016), which focused on a broader region of Ecuador, the Chilean and the Peruvian studies were circumscribed to public schools located in a single city and, therefore, they focus on more homogeneous settings in terms of both process quality and children's outcomes.

Early childhood education in Brazil

Brazil is a federation and the education administration is decentralized. States and municipalities play a crucial role in ensuring the provision and quality of early childhood education, primary and secondary education in public schools. Municipalities are responsible for ECE provision: crèches for children ages 0–3 and preschool for children ages 4–5.

In 2009, preschool (ages 4 and 5) became part of compulsory education, and the 2014 Plano Nacional de Educação [National Education Plan] was the first official document to commit to the universalization of preschool. In the last two decades, the coverage of ECE has dramatically risen: the percentage of children aged 0-3 attending crèche increased from 13.8% in 2001 to 37.0% in 2019, and children aged 4 and 5 attending preschool from 66.4% up to 94.1% in the same period. According to the 2019 school census, 66.6% of the children attended ECE in public institutions and 33.4% in private ones that work on full-day or half-day schedules. Moreover, 62.1% of teachers working in ECE had a university degree in Pedagogy (according to national guidelines law, a university degree in pedagogy is desirable to work in ECE settings. However, a high school degree, pedagogy modality, is acceptable. The National Plan of Education [2014–2024] sets a goal to have all ECE teachers with a university degree in pedagogy until 2024), 14,9.5% other teaching university degrees, 3,1% other university degrees, and 19.9% did not hold a college degree. The average preschool size was 17.7 children per classroom. In the specific context of public schools in Rio de Janeiro, the average preschool size is larger, 23.3 children per classroom and 39,3% of the working in ECE had university degree in pedagogy, 32.6% other teaching university degrees, 7.8% other higher education degrees, and 20.3% did not hold a college degree (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2020).

Although the legislation has pushed the ECE agenda forward, the discussion regarding what defines ECE quality in Brazil is still very recent. The absence of a national ECE monitoring system reflects that. As a result, very few studies investigate the association between ECE quality and children's development. Campos, Bhering, Esposito et al. (2011) and Campos, Bhering, Gimenes et al. (2011) measured ECE quality using ECERS and ITERS in six capitals in Brazil. The quality measures were later used in a cross-section design to estimate the association between ECE quality measures and children's language and math development in the second grade of primary education. The study was a pioneer in associating ECE quality measures with children's cognitive development. However, the study design has many limitations, especially considering the lack of information between children's time in ECE (range from 2 to 5) and the period they participated in the standardized test (ages 7 and 8). A more recent study by Silva et al. (2019) investigated the association between quality measures of ECE using Measuring Early Learning Quality

and Outcomes (MELQO) and children's cognitive development, executive function, and socioemotional development. The study also presents a cross-section to correlate measures collected all in the same year.

The National Quality Parameters for ECE were created in 2006 and updated in 2018. They were the first to include principles and parameters regarding both structural and processual aspects of quality in different areas, such as (i) teacher education and career; (ii) curriculum, interactions, and pedagogical practices; (iii) interaction with families and community; (iv) classroom setting, materials and furniture, and others (Brazil, 2018). A national baseline curriculum for ECE was only established in 2017 (Brazil, 2017). The *Base Nacional Comum Curricular* organizes what children should learn. Their routine in ECE is divided into fields of experience with learning goals for different ages. It includes children's rights in learning, the importance of integrating education and care, and the role of play and interactions as pillars of the curriculum, expected to be present in all learning opportunities and experiences. Before, the only national curricular document available was the 2009 national curriculum guidelines (Brazil, 2010), which established broad guidelines for work in ECE settings and emphasized the role of play and interactions. Municipalities are expected to build on the national curriculum and establish their orientations, adding cultural and context-related aspects until 2022.

Methods

Participants and setting

The present study used a subsample of a larger longitudinal study conducted in Rio de Janeiro that tracked children over two years (2017–2018) in preschool and presents a probabilistic single-stage cluster sample (school as a primary unit). The larger study included 46 public schools stratified by local educational administrative areas and type of school supply (only ECE X ECE and fundamental education provision). The sample excluded private schools, which account for almost 40% of preschool enrollment in the city. All classrooms and children in the selected schools were included in the study (128 classrooms and 2,716 children (Bartholo, Koslinski, Costa, & Barcellos, 2020; Koslinski & Bartholo, 2019).

The longitudinal study had three waves of data collection on three dimensions of children's development (cognitive development, gross and fine motor skills, behavior and personal, social and emotional development): two collections in 2017, at the beginning and end of the school year (children ages four and five) and one additional data collection at the end of the 2018 school year (children age five and six). See Koslinski & Bartholo (2019) and Bartholo, Koslinski, Costa, and Barcellos (2020) for more details on the sample. Figure 1 illustrates the design of the longitudinal study.

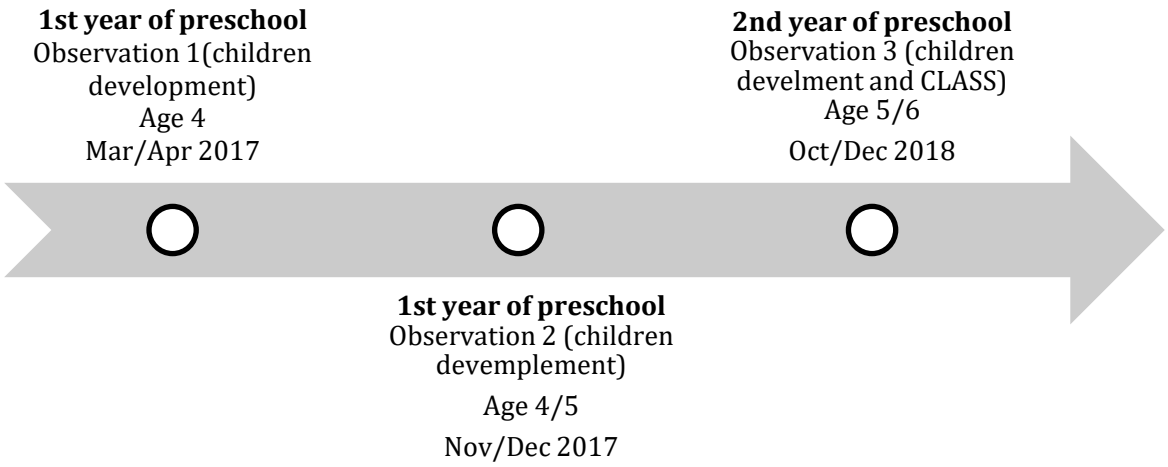


FIGURE 1 Longitudinal study design

All schools participating in the longitudinal study were eligible to take part in data collection on process quality which involved videotaping an entire school day during the third wave of observations (October and November of 2018). However, while contacting the schools to schedule the visits, 7 out of 46 schools refused to participate in the data collection on school process quality. The principals of those schools argued that teachers were not comfortable with the filming procedures. Therefore, we have randomly selected 60 classrooms from the 39 schools that agreed to participate in the videotaping. The 39 schools were spread throughout the municipality's 11 local education administrative areas.

The final sample size for the analysis presented in this paper included 59 classrooms and approximately 950 children. The videotaping of the classrooms took place in October and November of 2018, just before the third wave of children's assessment.

Classroom-level assessment

The videotaping took place for the entire school day (3 to 4 hours of filming). It was restricted to the classroom activities with the regular teacher (it excluded, for example, physical activity and meals that took place in other parts of the school). Only 3 to 4 hours of the morning shift was recorded in full-day classrooms. The visits were scheduled to capture an average day and avoid atypical situations (field trips, specific festive celebrations, or days when children spent less time with the regular teacher). Four 20-minutes segments for each classroom were selected for coding, following the guidelines described by Pianta et al. (2008): a) cycles with 20 minutes duration without interruption; b) segments including beginning, midday, and end of the day periods; c) segments with at least five children and the teacher in the video.

The videotaped material was coded by seven assessors that participated in a three-day PRE-K CLASS training delivered by Teachstone in July 2019. The assessors were certified by Teachstone reliability test at the beginning of August 2019 and have coded the videotaped segments from August to October 2019. However, each segment video had the codification of only one Teachstone certified assessor and, therefore, we could not conduct inter-rater reliability tests.

The coding used the CLASS protocol described in Pianta et al. (2008), considering three teacher-child interaction domains (emotional support, classroom organization, and instructional support), ten dimensions, and the 7-point scales. As a result, the assessors that coded classroom quality material were not the same as those assessing children's outcomes.

Child assessment and child-level covariates

The childrens' cognitive development was assessed at each wave of the study, using an adapted version of the Performance Indicators in Primary Schools (PIPS) instrument, a tool developed by researchers at Durham University in England (Tymms, 1999). The instrument measures two dimensions, language, and mathematics, which are composed of the following subdimensions: a) writing; b) vocabulary; c) ideas about reading – evaluates concepts about prints; c) phonological awareness; d) letter identification; e) word recognition and reading; f) ideas about mathematics; g) counting and numbers; h) addition and subtraction without symbols; i) identification of forms, and j) identification of numbers. See Bartholo, Koslinski, Costa, Tymms et al. (2020) for more information on the adaptation. The scores for language and mathematics were estimated from the cognitive test items of the adapted PIPS test using Rasch measures (Boone, 2006) in the Winstep software.

The study used the data collected at the end of the first year (November/December of 2017) and at the end of the second year of preschool (November/December of 2018). In addition to the children's cognitive data, the longitudinal study collected information from the family context during waves 2 and 3 by administering questionnaires to parents and guardians. The demographic data on the children (age, race/ethnic background and gender) and the additional data on the socioeconomic context of the family (education of the parents and participation in a cash transfer program – Bolsa Família) were obtained from the Academic Management System of the Municipal Department of Education (Sistema de Gestão Acadêmica da Secretaria Municipal de Educação; SGA/SME).

Based on extensive missing value analysis that suggested random distribution (Missing at Random), missing data was imputed using MICE (Multiple Imputation by Chained Equations) methods. As a result, all cases with missing values in our sample were imputed. However, only contextual and cognitive variables in our data were imputed.

Thus, domains and factors associated with teacher-child interactions were not included in that analysis (not imputed).

Data analytic approach

The first analysis conducted a confirmatory factor analysis (CFA) to investigate whether the three CLASS interaction domains reported by Hamre et al. (2013), Leyva et al. (2016), and Hanno et al. (2020) fitted the data from Rio de Janeiro public preschool classrooms. Afterward, we tested for the linear correlation between CLASS domains and end of preschool early maths and language outcomes. We used multilevel analysis technics and fitted separate models for each outcome. The first set of models included child-level covariates (sex, age, ethnic background, family socioeconomic status) and type of ECE provision. The second set of models also included the baseline measures (language or early maths measured at the end of the first year of preschool) as a control variable.

Table 2 below shows the variables, including their respective descriptions, mean, standard deviation and percentage of missing values. During collecting childrens' cognitive data on language and mathematics, we also collected contextual data from families. It is widely documented in the social science literature at large-scale research that information collected from individuals usually has a considerable percentage of missing value (Berchtold, 2019).

TABLE 2 Descriptive statistics for our sample at child level

	TYPE	*DESCRIPTION*	*M*	*SD*	*% Missing*
Language 2	cont.	Cognitive measure	.25	.87	9.5
Language 2 (imp)	cont.	Imputed cognitive measure	.24	.87	0
Language 3	cont.	Cognitive measure	.92	.93	0
Math 2	cont.	Cognitive measure	-1.86	1.35	9.5
Math 2 (imp)	cont.	Imputed cognitive measure	-1.88	1.35	0
Math 3	cont.	Cognitive measure	-.54	1.51	0
Sex	dich.	Male = 1	.52		0
Race	dich.	Non-whyte = 1	.63		7.7
Race (imp)	dich.	Imputed race (non-whyte =1)	.63		0
SES[2]	cont.	Socioeconomic index	.27	1.44	11.1
SES (imp)	cont.	Imputed socioeconomic index	.29	1.43	0
Age	cont.	Age at second wave	5.09	0.33	.2
Age (imp)	cont.	Imputed age at second wave			0
Number of children			947		
Number of classrooms			59		

Note. [2] Socioeconomic index calculated including items based on parental education, ownership of assets and poverty (access to cash transfer program).

Results and discussion

Table 3 shows descriptive statistics for domains of teacher-child interactions assessed by CLASS in the second year of preschool. The means scores of all three domains are similar to what was reported by Leyva et al. (2015) in a sample in the city of Santiago, Chile, but slightly lower than what was reported by Hanno et al. (2020) in a sample in Lima, Peru, or prior research in the United Stated (Hong et al., 2019). Nonetheless, the standard deviation for the Brazillian sample for emotional support and classroom organization is much higher than the sample in Chile and Peru, which might suggest that there are more inequalities regarding the quality of process in Rio de Janeiro public schools.

TABLE 3 Descriptive statistics for domains of CLASS

	M	*SD*	*Range (min-max)*
Emotional support	4.59	1.01	1.94 - 6.56
Classroom organization	4.62	1.10	1.58 - 6.92
Instructional support	1.93	.50	1.00 - 3.25

Note. N = 59.

Table 4 shows the correlation matrices for all the domains of teacher-child interactions measured by CLASS. Again, the coefficients indicate a positive association among all domains. Nonetheless, it is possible to observe that some domains are modestly correlated, for example, positive climate and concept development (0.29) or language modeling (0.26) and other moderately correlated – such as positive climate and instructional learning format (0.69) or behavioral management and instructional learning format (0.72).

TABLE 4 Descriptive statistics and correlation matrices among dimensions by CLASS

	NC	*TS*	*RSP*	*BM*	*PD*	*ILF*	*CD*	*QF*	*LM*
PC	.559**	.830**	.618**	.566**	.477**	.688**	.290*	.680**	.264*
NC		.464**	.417**	.570**	.279*	.422**	.223	.242	.126
TS			.603**	.615**	.620**	.702**	.332*	.647**	.321*
RSP				.429**	.437**	.610**	.293*	.525**	.487**
BM					.535**	.717**	.358**	.296*	.185
PD						.637**	.281*	.467**	.303*
ILF							.505**	.535**	.439**
CD								.455**	.608**
QF									.412**

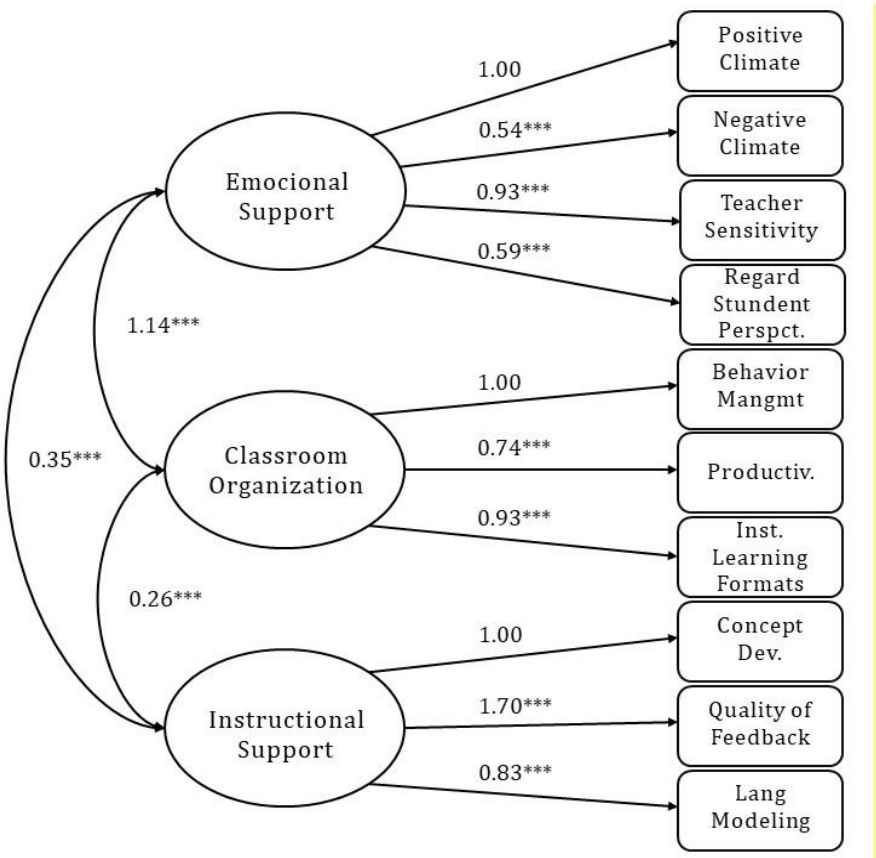
Note. PC = Positive Climate; NC = Negative Climate; TS = Teacher Sensitivity; RSP = Regard for Student Perspectives; BM = Behavioral Management; PD = ; ILF = Instructional Learning Format ; CD = Concept Development ; QF = Quality of Feedback.
** Correlation is statistic significant at 0,01 (bilateral).
* Correlation is statistic significant at 0,05 (bilateral).

The first research question aims to understand whether the evidence supports three specific domains of teacher-child interactions in Rio de Janeiro public schools. The first confirmatory factor analysis (CFA) suggested that the three-factor domains model (emotional support, instructional support, and classroom organization) did not fit the data well. Modification indexes analysis showed that CFA model (2) adjustment would improve if we included correlated residuals of the following dimensions: positive climate and concept development, behavior management and negative climate, quality of feedback and negative climate, productivity and teacher sensitivity, language modeling and regard student perspective, quality of feedback and behavior management, language modeling and behavior management, concept development and instructional learning format, language modeling and instructional learning format, instructional learning format and concept development. After including the correlated residuals from model 1, the fit of the models was better if compared to models with only two or three factors. Leyva et al. (2015) and Hanno et al. (2015) conducted the same procedures to improve the model fitted. Finally, as a robustness test, we run a model including only two factors (3) putting emotional support and classroom organization as one factor.

Results presented in Table 5 suggest that the second model showed robustness evidence that our sample data has three specific domains of teacher and child interactions by CLASS. Furthermore, chi-square difference testing analysis suggested that model 2 fit statistically better than models 1 and 3.

TABLE 5 Model fit statistics from Confirmatory Factor Analysis (FCA)

	Model 1 - three factors	*Model 2 - modified three factors*	*Model 3 - two factors*
X^2	(32) 1376.865, p<.001	(21) 594.927, p< .001	(34) 1556.231, p< .001
CFI	0.782	0.907	0.753
TLI	0.694	0.801	0.674
RMSEA	0.211	0.170	0.217
SRMR	0.087	0.061	0.090



** p < .05. *** p < .001.

FIGURE 2 Fitted confirmatory factor analysis model

Figure 2 shows the diagram path and the factor loadings and correlations for model 2 (modified three factors). Overall, factor loadings are lower than the Chilean sample results (Leyva et al., 2015). The highest factor value was described as the quality of feedback (1.7) and the lowest factor loading was negative climate (.54). Therefore, we decided to summarize in a Table 6 the correlation between factors included to fit model 2.

TABLE 6 Correlation between factors included to fit model 2 (modified three factors)

	BM	*PD*	*CD*	*QF*	*LM*
PC			-.05***		-.04***
NC	.36***			-.14***	-.11***
TS		.19***			
RSP					.13***
BM				-.19***	-.11***
PD					
ILF			.09***		.03***

Note. *** Correlation is statistic significant at .01 (bilateral).

The second analysis aims to estimate children's cognitive development in preschool and observe if teacher-child interactions are good predictors. Previous research with similar research questions presented different designs and, therefore, we will explore our data with cross-sectional and longitudinal analysis. Both models provide different insights and allow a more robust comparison with previous research using CLASS to predict cognitive development in Latin America.

Table 7 presents the coefficients of four separate multilevel models estimating children's language development at the end of the second year in preschool. The models do not have baseline control (primary cognitive measure) and are very similar to the analysis presented by Hanno et al. (2020) in Lima, Peru. CLASS domains were estimated separately and all together.

TABLE 7 Multilevel models estimating language development (cross-sectional)

	(1)	*(2)*	*(3)*	*(4)*
Intercept	-2.28	-2.27	-2.24	-2.23
	(-3.34|-1.22)	(-3.33|-1.21)	(-3.49|-1.41)	(-3.44|-1.30)
Sex	-.18	-0.18	-.19	-.19
	(-0.29|-0.07)	(-.29|-.07)	(-.29|-.08)	(-0.30|-0.08)
SES	.17	0.17	.17	.17
	(.13|.21)	(.13|.21)	(.13|.21)	(0.13|0.21)
Age	.65	.65	.64	.65
	(0.46|0.84)	(0.46|0.84)	(0.45|0.84)	(0.45|0.84)
Race	-.12	-.12	-.12	-.12
	(-.23|-.01)	(-.23|-.01)	(-.23|-.01)	(-.23|-.01)
Emotional Support	.01			-.02
	(-0.07|0.11)			(-.15|.11)
Classroom Organization		.01		-.01
		(-0.06|0.09)		(-.12|.10)
Instructional Support			.15	.19
			(-.01|.32)	(-.01|.39)
Only ECE	.10	.11	.08	0.10
	(-.09|.29)	(-.07|.29)	(-.09|.26)	(-.08|.29)
Observations	947	947	947	947

Note. Values depicted within parentheses represents 95% confident intervals.

The coefficients estimated in models 1, 2 and 3 suggest a positive association between all three CLASS domains and language development at the end of the second year in preschool. Instructional Support is more associated with language development – effect size of 0.09, and it is statistically significant at 0.05, despite the small sample of classrooms in the study. Model 4 presents all CLASS domains together, and the results indicate two crucial changes: the coefficients for Classroom Organization and Emotional Support shows a negative association with language development. These are small associations and not statistically significant. However, Instructional Support, even after controlling for all covariates, presents a larger and statistically significant coefficient – effect size 0.10 – with language development (effect sizes are reported in Table 10).[1]

[1] The effect sizes (Cohen's d) were calculated using the same procedures as NICHD ECCERN & Duncan (2013), Burchinal et al. (2010), Leyva et al. (2016), and indicate the change in the outcome variable expressed in standard deviation units when the predictor is also increased by one standard deviation.

Table 8 shows the same models estimating mathematics development at the end of the second year in preschool. Emotional Support presents a positive association, not statistically significant, with mathematic development in models 1 and 4. Classroom Organization presents a negative correlation with mathematic – see models 2 and 4 and the coefficients are not statistically significant. Instructional Support presents a larger association statistically significant coefficient at 0.10 – similar to what was observed estimating language development.

TABLE 8 Multilevel models estimating mathematics development (cross-sectional)

	(1)	*(2)*	*(3)*	*(4)*
Intercept	-6.73	-6.50	-6.96	-6.73
	(-8.43|-5.03)	(-8.20|-4.80)	(-8.63|-5.30)	(-8.43|-5.02)
Sex	.12	.12	.12	.12
	(-.04|.30)	(-.04|.30)	(-0.05|0.30)	(-.05|.30)
SES	.26	.26	.26	.26
	(.20|.32)	(.20|.32)	(.20|.32)	(.20|.32)
Age	1.24	1.24	1.23	1.22
	(.93|1.54)	(.93|1.55)	(.92|1.53)	(.91|1.53)
Race	-0.17	-0.17	-0.17	-0.17
	(-.35|0.007)	(-.35|.008)	(-.35|.008)	(-.35|.01)
Emotional Support	.02			.04
	(-.11|.15)			(-.15|.24)
Classroom Organization		-.03		-.12
		(-.16|.08)		(-.30|.04)
Instructional Support			.20	.28
			(-0.05|0.46)	(-0.01|0.59)
Only ECE	-.02	.01	-.04	-.02
	(-.32|0.27)	(-.27|0.30)	(-.32|.22)	(-.31|.26)
Observations	947	947	947	947

Note. Values depicted within parentheses represents 95% confident intervals.

The cross-section analysis suggests that instructional support is a good predictor of language and mathematic development at the end of preschool in Rio de Janeiro public schools. Even though the study has a small sample of classrooms (a total of 59), there are clear patterns for the coefficients estimating instructional support, which suggests that this specific CLASS domain has a linear association and can predict children's cognitive development. This is similar to what Leyva et al. (2016) found in the analysis in Chile and also the results reported by Hong et al. (2019) meta-analys and Perlman et al. (2016) systematic review for the US context. On the other hand, the emotional support and classroom organization coefficients present a much smaller association with language and mathematics development. Preliminary results suggest no clear pattern – coefficients

change from positive to negative correlation depending on the number of variables in level 2.

The final analysis presents longitudinal data to estimate CLASS domains as predictors of children's cognitive development. Leyva et al. (2015) presented a similar model with a sample of children from Santiago, Chile. Nonetheless, our models present more covariates, such as socioeconomic status index and ethnic background/race. The model is very similar to the cross-section analysis (see Tables 6 and 7), with the addition of baseline measures for children's language or mathematics development. Prior ability is by far the best predictor of later attainment and, therefore, this is a much more robust model. In addition, it is possible to observe that all the coefficients estimated (including Level 1 variables) change, highlighting the importance of baseline measures better to understand school/teacher effect on children's development.

Table 9 presents the results of four multilevel modeling analyses examining the association between CLASS domains with children's language development in the second year of preschool. Again, we use a baseline measure (end of the first year in preschool) to predict later attainment. Children attending a school focused only on early childhood education seem to benefit more than those attending a preschool that offers primary education. This is an important finding that should be analyzed more carefully in future research.

TABLE 9 Multilevel models estimating language development (longitudinal)

	(1)	*(2)*	*(3)*	*(4)*
Intercept	.11	.17	-.002	.11
	(-.63|.86)	(-.57|.92)	(-.73|.73)	(-.64|.87)
Language	.75	.75	.75	.75
	(.71|.80)	(.71|.80)	(.70|.80)	(.71|.80)
Sex	-.08	-.08	-.08	-.08
	(-.15|-.006)	(-.15|-.005)	(-.15|-.005)	(-.15|-.006)
SES	.05	.05	.05	.05
	(.03|.08)	(.03|.08)	(.03|.08)	(.03|.08)
Age	.14	.14	.14	.14
	(.01|.28)	(.01|.28)	(.01|.27)	(.01|.27)
Race	-.07	-.07	-.07	-.07
	(-.14|.004)	(-.14|.004)	(-.14|.004)	(-.14|.005)
Emotional Support	-.01			-.001
	(-.08|.05)			(-.10|.10)
Classroom Organization		-.02		-.04
		(-0.08|0.03)		(-0.13|0.04)
Instructional Support			.03	.08
			(-.09|.16)	(-.07|.23)
Only ECE	.12	.13	0.10	0.12
	(-.01|.27)	(-.008|.27)	(-.03|.24)	(-.01|.27)
Observations	947	947	947	947

Note. Values depicted within parentheses represents 95% confident intervals.

Emotional support and classroom organization present a negative correlation with language development. This is unexpected, but it should be highlighted that the coefficients are very small (especially in the case of emotional support) and not statistically significant. Instruction support presents a different outcome. Models 3 and 4 suggest a positive association and, although they are not statistically significant, it is important to reinforce that there is a clear pattern in the outcomes, and interval confidence suggests that the coefficients should be considered, especially in a study with a small sample of classrooms.

Table 10 shows the results of four multilevel modeling analyses examining the association between CLASS domains with children's mathematics development in the second year of preschool. The coefficients of all three CLASS domains present a similar pattern of the cross-section design (see Table 7). Controlling for baseline assessment, emotional

support, and instructional support positively correlates with mathematic development. Instructional support is more correlated to the outcome variable, and interval confidence suggests that this is an outcome that researchers and policymakers should consider in further investigation.

TABLE 10 Multilevel models estimating mathematics development (longitudinal)

	(1)	*(2)*	*(3)*	*(4)*
Intercept	-.49	-.25	-.54	-.41
	(-1.64|.66)	(-1.41|.89)	(-1.68|.60)	(-1.57|.75)
Math	.84	.84	.84	.84
	(.79|.89)	(.79|.89)	(.79|.88)	(.79|.88)
Sex	.18	.18	.18	.18
	(.07|.30)	(.07|.29)	(.07|.29)	(.07|.29)
SES	.05	.05	.05	.05
	(.01|.09)	(.01|.09)	(.01|.09)	(.01|.09)
Age	.28	.28	.28	.27
	(.07|.49)	(.07|.49)	(.07|.48)	(.07|.48)
Race	-.05	-.05	-.05	-.05
	(-.17|.05)	(-.17|.06)	(-.17|.06)	(-.17|.06)
Emotional Support	.01			.07
	(-.07|.10)			(-.05|.21)
Classroom Organization		-.04		-.11
		(-.12|.03)		(-.23|.002)
Instructional Support			.06	.10
			(-.11|.23)	(-.10|.30)
Only ECE	.01	.05	.01	
	(-.17|.21)	(-.13|.24)	(-.16|.20)	
Observations	947	947	947	947

Note. Values depicted within parentheses represents 95% confident intervals.

Classroom organization negatively correlates with mathematic development, and the coefficients are statistically significant. The result is similar to what has been reported by Hong et al. (2019) and Perlman (2016) that found inconsistent results for linear associations between classroom organization and different children's cognitive outcomes. There is some hypothesis that could help to explain this outcome. The most plausible is that our measures for classroom organization, especially for the productivity dimension, are slightly higher than what has been reported in other studies in Latin America. An additional reliability test (double coding from CLASS-certified researchers) could help better understand the quality of the measure.

Multilevel models suggest that instructional support is positively correlated with language and mathematics development, even after controlling for baseline measures.

This is an important finding and the lack of statistical significance should not be interpreted as an indication that this is a domain that is not relevant to predict children's cognitive development in preschool. The total number of classrooms in the study is relatively small (a total of 59). Therefore, the large *p*-value calculated in some models should not be interpreted in the conventional dichotomous way. Table 11 summarizes the effect sizes calculated for all CLASS domains. It is possible to observe that instructional support is most often more associated with language and mathematics development and positively correlated in all eight models.

TABLE 11 Effect sizes (cohens' d) for Class domains – cross sectional, and longitudinal models

	CROSS SECTIONAL							
	Language				*Mathematics*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
ES	.04			-.03	.02			.04
CO		.03		-.01		-.30		-.11
IS			.09	.10			.08	.11
	LONGITUDINAL							
	Language				*Mathematics*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
ES	-.01			.00	.01			.06
CO		-.03		-.05		-.03		-.09
IS			.04	.05			.02	.04

Study limitations

The study presents four limitations regarding internal and external validity (Shadish et al., 2002). The first is a relatively small sample of 59 classrooms included in the multilevel model analysis. The meta-analysis estimating the impact of CLASS measures in children's development conducted by Perlman et al. (2016) and Hong et al. (2019) suggests that larger samples more frequently find statistically significant coefficients.

Attrition in the longitudinal study is also a concern. There are two sources of attrition: a) pupil level – children that changed school or did not complete the cognitive assessment in a particular wave (total of 9.5%) and; b) school/teacher level: schools/teachers that did not want to have their classroom recorded (total of 15%). Missing data were handled with imputation at the child level and results did not vary using observed or imputed data.

The study sample only considered public schools in Rio de Janeiro. Nonetheless, there are many children frequenting preschools in private settings – 35,6%, according to the 2020 school census. This is relevant because most children enrolled in private schools pay fees, and there is significant segregation between public and private schools (Bartholo & Costa, 2018). Assessing only public schools means less variation in children's SES, cognitive development, and school characteristics and quality.

The last limitation is the lack of reliability tests for CLASS measures. All assessors were certified by Teachstone in August 2019 and started to code the material in the same month. Lack of additional funding unable the double coding for the reliability test. Despite all the limitations, the study is unique in crucial aspects. We collected longitudinal data for children's cognitive development using an adaptive test (PIPS) and CLASS to predict their progress. Previous studies in Brazil had a cross-section design, fewer covariates in the model, and did not use CLASS as a measure of ECE quality (Campos, Bhering, Esposito et al., 2011; Campos, Bhering, Gimenes et al. 2011; Silva et al. 2019).

Conclusion

Considering the significant investment across different countries to improve ECE programs' provision and quality, it is essential to understand the mechanisms that enhance children's development. The paper presents the first large-scale longitudinal study in Brazil that used CLASS domains to estimate cognitive development in public preschools in Brazil. The analysis suggests that the three-factor structure of CLASS domains was appropriate for the Brazilian context.

Multilevel models show that instructional support positively affects language and mathematics development, even after controlling for baseline measures. The coefficients estimated in the more robust models did not show statistical significance. However, it should be highlighted that the study has a relatively small sample of classrooms, and interval confidence should also be used to proceed with the interpretations.

The study found larger effect sizes for CLASS domains (especially instructional support) compared to previous research in Latin America. This critical finding reinforces that teacher-child interactions should be considered essential to explaining children's cognitive development. Moreover, it indicates that the recent expansion of ECE provision in Brazil should be followed by policies focusing teachers training, in order to improve classroom interactions and to achieve positive impacts on children development. The models also show that, on average, children seem to benefit more when attending schools focused on ECE programs. This is consistent with findings of previous studies focusing public ECE centers in a different Brazilian city (Koslinski & Bartholo, 2020). Future analysis should investigate the elements that could help explain the outcome and provide evidence to guide further policy and ECE expansion in Brazil.

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