Journal of Applied Developmental Psychology 66 (2020) 101084

Contents lists available at ScienceDirect

Journal of Applied Developmental Psychology

journal homepage: www.elsevier.com/locate/jappdp

Children's school readiness skills across the pre-K year: Associations with teacher-student interactions, teacher practices, and exposure to academic content☆

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ARTICLE INFO

Keywords:
Pre-kindergarten
School readiness
Classroom processes

ABSTRACT

The present study reports associations between features of directly observed classroom processes and school readiness skills across the academic year for 1498 children enrolled in publicly funded pre-K programs in a large and diverse county. In models adjusting for a range of child and family covariates, evidence was detected for the separate, and on occasion additive, associations of several classroom process features with children's skills – overall quality of teacher-student interaction, teachers' direct involvement in educational activities, the rigor of those activities in terms of difficulty, and children's exposure to academic content. Associations were not widespread or large, and overall children's performance appeared to increase modestly when classrooms were more educationally focused and structured, and teachers were supportive and responsive as they were involved with children. Results are discussed in light of efforts to improve the benefits of pre-K programs on children's learning.

Introduction

Public investment in early education serves as an important means of mitigating opportunity gaps that can have long-term consequences for individual children and for society at large (Barnett et al., 2018; Bloom & Weiland, 2015). At present, almost 70% of low-income 4-year-olds across the country are enrolled in public preschool programs (Barnett et al., 2018); 40 states now serve > 1.3 million children, and Head Start serves an additional 900,000 children per year. Given this widespread deployment of public early education, for many children this represents the start of their educational careers. Although these educational opportunities offer promise for improving children's early learning, typical programs offered in the United States do not deliver consistently on this promise (Barnett et al., 2018; Bloom & Weiland, 2015; Lipsey, Farran, & Durkin, 2018). As evidence, as many as half of children from low-income families are not ready for the first day of kindergarten with regards to their academic and social-emotional skills, as well as their physical health (Isaacs, 2012), and only a quarter of children across the country meet expectations for literacy and math at school entry (Bernstein, West, Newsham, & Reid, 2014). Some large-scale evaluations suggest that pre-K has only small effects that may fade over time and be undetectable by third grade (Camilli, Vargas, Ryan, & Barnett, 2010; Lipsey et al., 2018; Puma et al., 2012), raising questions concerning the nature and value of pre-K opportunities and how to improve them.

Importantly, recent evaluations of successful state and city models suggest a cluster of malleable aspects of the pre-K classroom setting that may be effective in improving student outcomes and that warrant closer attention – features of teacher-child interactions, content and rigor of instruction, and time exposed to academic content (Bloom & Weiland, 2015; Keys et al., 2013; Minervino, 2014). Closer examination of these aspects of the classroom setting may provide information that helps the field shift from the questions of whether pre-K has an impact on learning to a focus on which aspects of pre-K experiences are

☆ We gratefully acknowledge the support of our many partners: school district leaders, community programs, teachers, parents and children. Their enthusiastic cooperation and participation made much of this work possible. We also extend appreciation and recognition to Marcia Kraft-Sayre, Marianna Lyulchenko, Laura Helferstay, Brittany Kerr, and Emily White who each made valuable contributions to the project. The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant #R305N160021 to the University of Virginia. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education. Request reprints from author Pianta at rcp4p@virginia.edu.

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https://doi.org/10.1016/j.appdev.2019.101084
Received 1 March 2019; Received in revised form 25 October 2019; Accepted 28 October 2019

particularly effective in improving outcomes for low-income children. The present study seeks to link variation in three aspects of classroom processes: teacher-child interactions, content and rigor of instruction, and time exposed to academic content, with children's school readiness skills over the pre-K year.

Gaps in understanding the effects of pre-K

Various "state of the field" reviews and analysis of program impacts conclude that the modal pre-K (or even K – 3) experience for low-income children is not sufficiently educationally intensive to close skills gaps at kindergarten entry or to promote learning that lasts through the elementary grades (Auger, Farkas, Burchinal, Duncan, & Vandell, 2014; Barnett et al., 2018; Camilli et al., 2010; Pianta, Barnett, Burchinal, & Thornburg, 2011). These conclusions correspond to evaluations that, in the main, reveal somewhat inconsistent conclusions regarding pre-K program impacts. With respect to benefits, studies of contemporary state-funded pre-K programs have associated enrollment to student learning gains in the pre-K year and for some, even through third grade—for programs in Texas (Andrews, Jargowsky, & Kuhne, 2012), North Carolina's Smart Start and More at Four programs (Ladd, Muschkin, & Dodge, 2014) and in New Jersey's Abbott pre-K program (Frede, Jung, Barnett, & Figueras, 2009), among others; findings supporting the benefits of state pre-K programs that were confirmed by Barnett et al. (2018). Yet, there are also studies showing null or fading effects, several of which use experimental designs. For example, Lipsey et al. (2018) found that the short-term benefits of Tennessee's Voluntary pre-K program faded by the end of first grade. Bloom and Weiland (2015) investigated impacts of the federal Head Start program and reported widely varying impacts across grantees, with many showing no impact and some showing large effects; while Magnuson, Ruhm, and Waldfogel (2007) reported convergence for academic outcomes by the end of first grade in their analysis of the Early Childhood Longitudinal Study. A significant volume of research in the field seeks to identify empirical findings that explain these apparent inconsistencies.

In most of evaluations of pre-K, explanations for null, positive, or even negative effects most often rest on inferences related to the nature of children's experiences of classroom processes—including the nature and quality of interactions, the curriculum, and the quality and differentiation of teachers' instruction (Barnett et al., 2018; Keys, Farkas, Burchinal, Duncan, Vandell, Li & Howes, 2013; Phillips et al., 2017; Yoshikawa et al., 2013). Although certain of these features have been included in many of these studies (e.g., Lipsey et al., 2018), not every study includes direct assessments of several key classroom process indicators. The present study fits within this larger framework of efforts to detect associations between pre-K classroom processes and child outcomes; this specific report focuses on associations between three forms of directly observed classroom processes—interactions, content, and dosage of instruction—and children's skills across the pre-K year.

Classroom processes: Interactions, content, and dosage of instruction

Education opportunities influence children's learning largely as a consequence of experiences in classrooms (Nye, Konstantopoulos, & Hedges, 2004; Pianta, Belsky, Vandergrift, Houts, & Morrison, 2008). Therefore, to improve the impact of investments in early education, it makes sense to focus on classroom features that could themselves be the focus of change, or improvement. Evidence points to three forms of malleable classroom process that consistently, albeit modestly, relate to student learning gains: the focus and rigor of instructional content made available in the classroom; children's exposure to such content; and the nature and quality of interactions between teachers and students. Recent experimental studies demonstrate that these three forms of classroom process are indeed malleable. For example, teacher-student interactions and instructional practices can be improved through focused coaching (Pianta, Mashburn, Downer, Hamre, & Justice, 2008; Yoshikawa et al., 2015), coursework (Hamre et al., 2012), and even viewing videos of effective teaching (Pianta et al., 2014). Similarly, the content of instructional activities to which children are exposed and the duration of time they are exposed can be modified through planning and instructional management (e.g., Connor, Morrison, & Slominski, 2006). Thus, targeting these malleable and salient processes through direct observation and identifying the extent to which they account for students' learning and developmental gains may provide a basis for directing efforts (policy, program design, professional development) to improve and intensify the contribution of pre-K to children's outcomes.

Rigor of instructional content

There is abundant evidence that children's exposure to content in a specific domain (e.g., math) is key for fostering learning in that domain (Barnett et al., 2018; Clements & Sarama, 2008; Connor et al., 2006), and that such experiences have to include exposure to content at the upper end of children's skills and understanding (defined here as "rigor") as much as exposure to basic or routine skills. For example, Connor et al. (2006) demonstrated the importance for learning gains of both exposure to instruction in basic literacy skills (e.g., letter names and sounds, rhyming) and the critical need to transition to instruction in higher level skills (e.g., reading words and sentences, comprehension). This pattern is also evident in math (Clements & Sarama, 2008), such that teachers' focus on skill and knowledge trajectories, reflecting the progression into more sophisticated performance, appears to be a key aspect of students' increased learning.

Dosage of instruction

At the same time, however, rigorous instructional content is not sufficient, in and of itself, to produce improvements in child outcomes. Children also have to be exposed to a sufficient dosage of such content through instruction. Occasional or inconsistent exposures to content are the norm in most pre-K classrooms. For example, evaluations of math programs in pre-K and elementary school demonstrate time spent on math instruction in general and on specific math content areas are key elements of a successful program (Camilli et al., 2010; Chien et al., 2010; Claessens, Engel, & Curran, 2014; Clements & Sarama, 2008; Weiland, Ulvestad, Sachs, & Yoshikawa, 2013). Results from recent observational studies of children's exposure to instruction in pre-K classrooms suggest that the average pre-K child is exposed to some form of instruction or learning activity for roughly a third of the time they spend in the classroom (e.g., Pianta, Whittaker, Vitiello, Ansari, & Ruzek, 2018), while almost 30% of time is devoted strictly to management and routine activities and another 40% devoted to non-academic or no content. And classrooms vary considerably in the level of exposure to instruction they provide to the average child.

Teacher-student interactions and practices

Teacher-student interactions, characterized by teacher sensitivity and responsiveness to children's cues, support for engaged and positive behavior, and stimulation of language and cognitive development, reflect a third malleable element of classroom process (Ansari & Pianta, 2018; Burchinal et al., 2016; Vernon-Feagans, Mokrova, Carr, Garrett-Peters, & Burchinal, 2018; Vitiello, Bassok, Hamre, Player, & Williford, 2018). Learning gains appear to be modestly greater when teachers emphasize conceptual understanding, provide feedback that extends students' skills, and engage children in conversations (Burchinal, Vandergrift, Pianta, & Mashburn, 2010; Pakarinen et al., 2011; Yeomans-Maldonado, Justice, & Logan, 2017). Similarly, children whose teachers create an organized and emotionally supportive classroom demonstrate improvements in self-regulatory and social-behavioral outcomes; in fact, children who display problems in self-regulation appear to benefit even more from exposure to effective teacher-child interactions (Hamre & Pianta, 2005; McCartney, Dearing, Taylor, & Bub, 2007; Vernon-Feagans et al., 2018). Multiple years of exposure to effective teacher-student interactions appears to be of additional

benefit (Cash, Ansari, Grimm, & Pianta, 2019; Vernon-Feagans et al., 2018).

Heterogeneity in the effects of classroom processes

To understand the impact of educational processes across the pre-K – 3 span, one has to consider how salient features of children's development interact with the educational process over time. Two sets of such features may be particularly relevant: 1) demographic characteristics of children and their families and 2) children's skills at pre-K entry. How programs and classrooms respond to these characteristics is a malleable and influential feature of classroom process and can ensure that children reap the maximum benefit from pre-K.

It has been suggested that the most influential child-level factor accounting for school success centers on demographics—the combination of financial, educational, and cultural variables that often forecast poor performance for a large number of children (Reardon, 2011). Children from low-income backgrounds are almost a full year behind at school entry in academic and language skills (Denton Flanagan & McPhee, 2009; Halle et al., 2009)—factors that publicly funded preschool programs were designed to address. Although not directly malleable as a function of pre-K programs and resources, demographic factors are important to examine in relation to matters of equity and access to effective educational programs because relevant district policies (such as eligibility criteria) or procedures *are* malleable and may be adjusted.

One demographic factor of pressing importance is a child's language-learning status. Although linguistically diverse children are less likely than their English-speaking peers to be enrolled in pre-K (Cannon, Jacknowitz, & Karoly, 2012), the expansion of publicly funded programs has increased the accessibility drastically for this population. However, there are challenges in how early education can best support children who are learning English as a second language. Dual Language Learners (DLLs), often enter preschool programs with little-to-no English exposure (Fortuny, Capps, Simms, & Chaudry, 2009; Hindman & Wasik, 2015), and confront the task of learning a second language before having mastered their first. They often demonstrate lower rates of learning than their English-speaking peers when provided with English-only instruction (Thomas & Collier, 2002). Conversely, studies show that DLLs often enter the classroom with significant strengths in their social-emotional and executive function skills (e.g., Halle et al., 2014), but these benefits are not always acknowledged or fostered in classroom environments (see Castro, García, & Markos, 2013). Therefore, we consider how DLLs and their monolingual peers experience pre-K, and whether they benefit from it differentially.

And as children enter preschool or kindergarten, their skills in key domains (e.g., language, literacy, math, and social skills) can also interact with teachers' instruction or social support, content, and dosage of exposure to content. These entry skills are important; once children start behind, it is difficult to catch up (Heckman & Kautz, 2013; Reardon, 2011). When districts or teachers measure children's school readiness, it provides information for optimizing classroom placements; formative assessment can be the basis of adjusting instruction throughout the school year to ensure that teachers meet individual children's needs (Connor et al., 2006). Accordingly, assessing the extent to which classroom features interact with children's skills at school entry can provide insight into which malleable factors can be leveraged to maximize program effectiveness.

Summary and aims

Systematic and rigorous empirical inquiry that examines associations between student learning to variation in key classroom processes may provide a rich and possibly more actionable set of results than high-stakes evaluations (e.g., Barnett et al., 2018; Lipsey et al., 2018; Puma et al., 2012). With respect to the outcomes of interest in the early years of school, children's skills in language, literacy, math, and social-emotional skills are the central focus of most states' early learning standards (Daily, Burkhauser, & Halle, 2010), the Federal Head Start early learning standards (USDHHS, 2015), and a large amount of effort in the areas of curriculum, assessment, and professional development. The present study examines the extent to which children's performance in key school readiness domains are related to three forms of educational process in pre-K classrooms (teacher-child interactions and practices, exposure to rigorous academic content, and dosage of instruction). We use covariates to control statistically for a variety of selection factors and potential confounds, including: a) child/family demographics; b) features of pre-K programs; and c) classroom and teacher-level factors. As part of this effort, we also explore the extent to which such associations are moderated by demographic factors (i.e., income, dual language learner status) and children's skills (i.e., literacy, language, math, social-emotional skills) at the start of the pre-K year.

Methods

The pre-K program setting

The present study sample was drawn from a large, culturally and linguistically diverse county in Virginia, serving over 150,000 students from pre-K through 12th grade, a size and scale similar to many states. The school system serves a rapidly growing percentage of vulnerable families and children, including a very substantial immigrant population, with 18% of families in which neither parent is a U.S. citizen. County students are highly diverse ethnically, with 39% White, 26% Hispanic/Latino, 19% Asian, 10% African American, and 6% other or mixed race/ethnicity. In pre-K, 53% of children have a home language other than English, and 38% are identified as Dual Language Learners (DLL). Ten percent of households have no full-time wage earner, one third of children qualify as low-income (a 40% increase in the ten years prior to 2013), and 25% receive public assistance.

The county public pre-K program blends funding from federal, state, and local sources to target low-income children. The county governing body is the local grantee for Head Start/Early Head Start and for the state pre-K program; the board also delegates funds to be managed by the school district and local non-profit groups which blend funding to provide low-cost or free pre-K. Nearly all (98%) children enrolled in public pre-K attend one of two main full-day (6–6.5 h) program types. The largest (school-based pre-K), serves over 1500 children in pre-K classrooms within schools. The second largest type (community-based pre-K), serves > 400 children by subsidizing slots in private pre-K (for- or non-profit) and Head Start centers. Governance, policy, regulation, and funding of pre-K programs are all coordinated through a central authority. For the classrooms located in elementary schools, teachers were required to have at least a Bachelor's degree and a relevant certification (e.g., early childhood, Pre-K – 6) and the class size was limited to 15. In classrooms located in Head Start centers, the majority of teachers had a Bachelor's degree and relevant certification and conformed to Head Start guidelines for class size. Classrooms located in community centers were staffed by teachers with minimal credentials of Associate's degrees and class size met state guidelines, which allowed multiple teachers in classrooms of up to 20 children.

Teacher participants

Teachers in the study were recruited from the entire population of school and community-based pre-K program classrooms. All teachers in the public school program were eligible; in community programs teachers were eligible if they taught at a center in which more than five publicly funded pre-K children were enrolled. At the start of the study, 156 teachers and their classrooms were initially recruited (100 from public schools, 56 from community programs). With the assistance of program staff, researchers identified a list of community childcare centers that were either publicly funded (e.g., Head Start) or included

slots for publicly funded children to attend. A flyer was sent to center directors describing the project, and centers were contacted individually. If center directors indicated interest in participating, researchers and program staff contacted teachers to describe the project in more detail and obtain teachers' consent. For the public schools, project information was distributed to teachers by the district coordinator. Teachers who opted to participate returned consent forms to the research team. Once we received a consent form, a teacher was considered to be enrolled in the study.

Of the 156 recruited teachers, 138 met eligibility requirements and enrolled in the study. A small subset of these enrolled teachers opted not to participate in teacher-level data collection (e.g., observations) but facilitated child assessments. The number of observed classrooms was 126 (87 from public schools, 39 from community programs). Lead teachers averaged 16.86 years of education and had 15.68 years of teaching experience. All classrooms and teachers met state requirements for teacher credentials, training, curriculum, and class size/ratio for their respective programs; Head Start classrooms met that program's guidelines as well.

At the beginning of the school year, participating teachers sent all parents or guardians of students enrolled in their classroom a consent form and short family demographic survey. Children were eligible to participate if they were enrolled in the pre-K program, turned 4 years of age by the start of the study, and were not receiving special education services (except for speech). Eighty percent of parents had children who were eligible to participate and consented to allow their child's participation in the study (1498 out of 1878 parents). For the children enrolled in the sample, half were boys (50%), and they averaged approximately 4.40 (SD = 0.29) years of age at pre-K entry. Children enrolled in the study were racially and ethnically diverse (61% Latino, 12% other, 20% Black, and 7% White), generally spoke a language other than English at home (55% Spanish, 24% other, and 21% English), and came from households with an income-to-needs ratio of 0.86 (SD = 0.53).

Characteristics of teachers, classrooms, and children participating in the study did not differ from corresponding indicators for the entire populations, respectively. Moreover, non-participants did not differ from participants.

Data collection procedures and measures

Data were collected through classroom observations, surveys, rating scales, and direct assessments. Observations were conducted on two (the minimum number) or three separate occasions during the pre-K year (M = 2.72, SD = 0.49; 74% had three observations, 25% had two observations, and 2% had one observation) while other data were collected via surveys in the fall and/or spring. During observations, data collectors observed classrooms across the morning from the start of the school day to lunchtime, alternating between assessing the quality of interactions with the Classroom Assessment Scoring System (CLASS; Pianta, Paro, & Hamre, 2008) and the content and dosage of instruction with the Behavioral Coding System (BCS), which was adapted from the NICHD SECCYD Classroom Observation System and Observational Record of the Caregiving Environment (McCartney et al., 2007; Pianta, Mashburn, et al., 2008) and informed by work by Ritchie, Howes, Kraft-Sayre, and Weiser (2001). Parents completed a demographic questionnaire reporting family income, household composition, parent education, and children's age, gender, and race, and received a small stipend to thank them for their time. Teachers completed a survey in the fall and spring reporting their demographic characteristics and experience, as well as attitudes, knowledge and beliefs. Teachers also completed rating scales on each participating child's social-emotional skills in the fall and spring, and received a small stipend at each time point to thank them.

Direct assessments of readiness skills were conducted for all children and classrooms in the fall (September – November) and spring (April – May) by trained data collectors. Data collectors completed a one-day training to learn the measures prior to assessing children. Children were assessed in a quiet space, outside of the classroom when possible. In the fall, children were assessed in English unless they failed the language screening (PreLAS); if this was the case, and if they spoke Spanish, then they were assessed with parallel Spanish measures (for the academic skills outcomes only) in the fall of pre-K in addition to the English assessments. In the spring, however, all children were assessed in English because prior analyses with this sample using the fall PreLAS indicated the fall assessment to underestimate children's skills in English. Given the increased exposure to English in the ensuing months, it was assumed that children's English skills would increase and the PreLAS would be an even less valid screener. Therefore, procedures were instituted through which data collectors asked teachers to review the names of children scheduled for assessment on a given day and indicate whether they thought the child was capable of understanding the test directions and responding in English. If the teacher indicated concerns, the child's data were flagged and not included in the analyses. The present study utilizes only the English-language assessment data for children indicated by teachers or by the Pre-LAS as capable of participating in the assessment. Fewer than 15 students were flagged by teachers and excluded from the analyses for reasons of language.

Classroom observations

Behavioral coding system (BCS)

The BCS observations focused on capturing information in four general areas of experience, namely: (a) activity setting, (b) instructional content, (c) teacher behaviors, and (d) child behaviors. For the purposes of this study, we focused on the first two codes, which we discuss below. It is important to note that the BCS is designed to provide an estimate of the experience of a *typical* child in the classroom. Accordingly, each observation cycle focused on a different child randomly selected from the participating children in the classroom, and scores were aggregated across cycles and then days to create classroom-level indicators for the different dimensions observed. BCS scores represent the proportion of intervals that target children were observed to experience for each type of code. Options for coding activity setting (e.g., whole group, free play) and instructional content (e.g., literacy, math) were exhaustive and mutually exclusive, such that one code (and only one code) was assigned for each item during each 30-s interval, representing the child's experience for the majority of that interval.

In order to implement the BCS, data collectors were required to complete a 1.5-day training, which included learning the codes and coding multiple master-coded videos. All data collectors were required to take and pass a reliability test to be certified to go into the field to conduct observations, which involved coding five cycles (50 30-s intervals) from video with 85% or greater agreement with master codes (i.e. coded present or not). All data collectors passed on the first attempt, with average exact agreement exceeding 90%. Moreover, roughly a quarter of classrooms were double coded in the fall and spring. Results from these double coding sessions indicate that coders agreed (exact agreement) on 87–88% of all BCS codes across all double-coded intervals, yielding a Cohen's Kappa of 0.50, indicating moderate agreement (Altman, 1991); Kappa increases to 0.58 if the very low frequency behaviors were omitted.

BCS activity setting

In each cycle of BCS observation, the focal child for that cycle was classified in an activity setting. *Teacher-directed activities* was a combination of *whole group* activities where children were part of an organized activity that included all or most of the class (e.g., circle time or book reading), *small group* activities where teachers organized children into smaller groups, and *individual activities* where teachers organized children to be working individually. The next activity setting was *free play*, whereby children selected how and with whom they wanted to

spend their time, and the final activity setting included a combination of *routines and transitions* (e.g., clean up, washing hands, waiting in line) and meals (e.g., eating snacks). For the purposes of the present study, the referent for all analyses was the proportion of intervals spent in *free play*.

BCS academic instructional content

Instructional content included codes for a variety of activities (i.e., academics, art, socio-emotional, other content, no content); however, for the purposes of this study we focus on the provision of *academic content* (i.e., language, literacy, math, science, and social studies). Similar to activity settings, only one instructional activity could be coded per 30-s interval and, thus, the focal child was classified based on the activity in which he or she spent the majority of the observation interval. Occasions in which the child was exposed to *academic content* (see above) were composited across children and cycles of observation to form an overall score reflecting the proportion of each form of academic content provided, at the classroom level.

The quality of teacher-child interactions

We used the Classroom Assessment Scoring System pre-K (CLASS pre-K; Pianta, Belsky, et al., 2008) to measure teacher-child interactions at the classroom level with 11 dimensions on a seven-point scale. Similar to the BCS, all data collectors attended a two-day training session and were certified on the tool in order to conduct observations. Raters were trained to an initial level of 80% agreement (within 1-point) to be certified for collection of data in the field. Data collector reliability was maintained with refresher training before data collection and regular calibration meetings. Twenty percent of all observed cycles (fall and spring) were double coded (two observers in the classroom) to determine inter-rater reliability. Average inter-rater agreement (across raters) for the double-coded live observations ranged from 62% to 91% across the 11 CLASS scales. We composited these ratings across dimensions and across occasions of observation into a single overall domain of *interaction quality* ($\alpha = 0.85$). During each classroom visit, observers conducted 4 cycles of observations (each cycle includes 15 min to observe, 10 min to score).

Teacher surveys

Teacher report of instructional rigor

In the spring of the pre-K year, teachers responded to a series of items on literacy and math instructional content. Items were adapted from the Early Childhood Longitudinal Study – Kindergarten: 2011 Cohort (ECLS-K:2011) teacher questionnaires following procedures similar to those used by Claessens et al. (2014). Literacy and math items were selected to represent a range of difficulty levels and content areas and were edited for clarity and to increase alignment to state standards and learning trajectories. The survey included 29 literacy items and 26 math items. For each item, teachers indicated whether the content was taught as part of general classroom instruction. To assist in scoring, we asked literacy and math content experts to identify whether each item was most appropriate for pre-K, kindergarten, first, or second grade; we then crosswalked their responses with the state standards local to the school district and consulted again with the experts to resolve any discrepancies. Items were assigned points according to these ratings (pre-K items were worth 1 point, kindergarten items were worth 2 points). For first-grade items (3 points) and second-grade items (4 points), teachers received points if they endorsed the item; if they did not endorse those items, they were treated as missing (i.e., teachers were not penalized in scoring for not endorsing these more difficult content areas). *Instructional rigor* was the code derived from the sum of these item score, with higher scores reflecting a classroom in which more rigorous content is taught, according to the teacher.

Teacher and classroom characteristics

In the fall of pre-K teachers completed a survey describing their own *demographic characteristics*, training, etc. as well as a number of classroom characteristics. From this survey, the following variables were selected and used as teacher covariates in analyses: *race* (non-white), *years of education*, *years of experience* as a teacher. The classroom characteristics selected from the survey and used as analytic covariates included: *mean age of children*; *percent minority* (non-white); *mean income to needs ratio*; *percent dual language learners*; *percent boys*; *class size*; and *classroom type* (public school, private center, or Head Start).

School readiness outcome assessments

Children's performance was assessed on a variety of school readiness domains, including academic achievement and social adjustment, using direct assessments as well as teacher reports.

Academic achievement

Children's academic achievement was directly assessed with four subtests from the Woodcock Johnson III Psychoeducational Battery (WJ-III; LaForte, McGrew, & Schrank, 2014). Children's literacy skills were assessed with the *Letter-Word Identification* subtest of the WJ-III, which asked children to identify individual letters and words and is a test of early reading ($\alpha = 0.94$). Language skills were assessed with the WJ-III *Picture Vocabulary* subtest ($\alpha = 0.81$), which required that children identify objects that were depicted in a series of pictures. Two subscales of the WJ-III were also administered to measure children's math skills: *Applied Problems* ($\alpha = 0.93$) required that children perform basic math calculations in response to orally presented problems and *Quantitative Concepts* ($\alpha = 0.91$) required children to identify number patterns.

Socioemotional skills

In the fall and spring of the pre-K year, children's teachers were asked to rate a series of items according to how well they described the study child. These items were pulled from the Student–Teacher Relationship Scale (STRS; Pianta, 2001) and the Teacher Child Rating Scale (TCRS; Hightower et al., 1986). The STRS was used to examine teachers' relationships with the individual children in their classrooms. This nine item measure was based on a 5-point scale (1 = *definitely does not apply*, 3 = *neutral, not sure,* 5 = *definitely applies*) and yielded two factors: *closeness* and *conflict*, which demonstrated good internal consistency (closeness $\alpha = 0.81$–84; conflict $\alpha = 0.89$–0.91). The TCRS is also based on a 5-point Likert scale (1 = *not at all*, 3 = *moderately well*, 5 = *very well*), but taps into four different dimensions of children's socioemotional skills: *frustration tolerance* (5 items, $\alpha = 0.90$–92), *task orientation* (5 items, $\alpha = 0.89$–91), *social skills* (5 items, $\alpha = 0.92$–0.94), and *conduct problems* (6 items, $\alpha = 0.89$–91).

Executive functioning

Children's executive functioning skills were assessed using three procedures. Working Memory was measured using the *Backwards Digit Span* subtest (LaForte et al., 2014), by asking children to repeat sequences of numbers in reverse that increase in length. It has a median reliability coefficient of 0.88. This task has been widely used in the developmental literature as a test of working memory. The *Head-Toes-Knees-Shoulders* assessment (HTKS; McClelland et al., 2007) was used to examine children's behavioral self-regulation. As part of the HTKS, children were required to do the opposite of what the data collector asked of them. Finally, inhibitory control was assessed using an adapted version of a standard peg-tapping task, using pencils rather than pegs (adapted from Diamond & Taylor, 1996; Luria, 1966; see Smith-Donald, Raver, Hayes, & Richardson, 2007). This *pencil tap* assessment asks children to tap once when the assessor taps twice and vice versa. The number of correct responses on this assessment has demonstrated good concurrent and construct validity with other measures of inhibitory

control as well as predictive validity for school readiness outcomes such as phonemic awareness (Blair & Razza, 2007).

Data analysis plan

Analyses on relations between pre-K classroom processes, child characteristics, classroom and teacher factors, and children's academic and socio-emotional outcomes were estimated within a multi-level modeling framework, which accounted for the nesting of children in classrooms. To address missing data, all models were estimated using full-information maximum likelihood (FIML), which utilizes all available data points from each individual in estimating model parameters, and is appropriate when data is missing at random (MAR).

Within this framework, a set of covariates that adjusted for a range of potential selection factors and confounding variables included: 1) baseline features (fall level of corresponding spring outcome, lag in days between fall and spring assessments); 2) child and family characteristics (child age, child gender, child race/ethnicity, child home language, child pretest scores, household income, and parent education), 3) teacher characteristics (race, years of education, and years of experience); 4) classroom characteristics [percent minority (non-white); percent dual language learners; percent boys, mean income to needs ratio; and class size]; and pre-K program auspice (community-based, Head Start or, public school). All variables were standardized, which provides grand-mean centering of measurements. Grand-mean centering, in tests of moderation, reduces inessential collinearity between the main effects and interaction terms.

Main effects of specific classroom processes were estimated net of all covariates mentioned above and net of the other classroom process variables. Thus, results of the final models present main effects for all predictor variables (i.e., covariates and classroom process indicators) adjusted for all other predictors in the model (Tables 3-5). Fixed effects were permitted to vary randomly. Once the independent main effects of the classroom process factors were examined in this way, net of covariates and remaining classroom processes, we then examined the extent to which any associations between classroom process factors and child outcomes were moderated by: child pretest scores, household income (income to needs ratio), and DLL status.

Results

Descriptive results for all focal variables are presented in Tables 1 and 2. All variables were examined for outliers and truncated to three standard deviations. A series of preliminary analyses also examined intraclass correlations reflecting variation in child outcomes at different levels of the multi-level framework. As is evident in Table 2, the vast majority of variation in children's academic achievement and executive functioning was found at the child level, leaving only a small percentage at the classroom level for explanation using the classroom process predictors (5–12% for achievement and 0–3% for executive functioning). In terms of teacher ratings of children's socioemotional skills, roughly 14–30% of the variation in these outcomes were found at the classroom level.

With regard to the primary research aims concerning the associations between classroom processes and school readiness outcomes, the main effects analyses for direct assessments of academic outcomes are presented in Table 3 while those for the socioemotional and executive function outcomes are presented in Tables 4 and 5, respectively. Because all predictors were standardized to have a mean of 0 and standard deviation of 1, effect sizes for all analyses reported were calculated as the coefficient of interest divided by the standard deviation of the outcome using three decimal places.

Main effects of classroom processes and children's school readiness

For academic skills (Table 3), in classrooms that were observed to have overall higher quality of teacher-student interaction, children demonstrated greater gains in applied problems and quantitative concepts (math) on the Woodcock-Johnson (effect size (ES) = 0.06–0.11). Additionally, children demonstrated greater gains in letter word identification (literacy) when they spent more time in teacher-directed activities ($ES = 0.09$) and classroom routines ($ES = 0.09$) in contrast to time in free play.

Table 1
Descriptive statistics for the study sample.

Child and family characteristics	
Age in months	52.82 (3.49)
Male	0.50
Race/ethnicity	
Black	0.20
White	0.07
Hispanic	0.61
Other	0.12
Home language	
English	0.21
Spanish	0.55
Other	0.24
Income to needs ratio	0.86 (0.53)
Parent years of education	12.63 (1.80)
Classroom and teacher characteristics	
Quality of teacher-child interactions	4.37 (0.49)
Teacher-directed instruction	0.38 (0.14)
Free play	0.30 (0.13)
Routines	0.32 (0.13)
Time spent in academics	0.35 (0.12)
Math level	1.65 (0.29)
Literacy level	1.53 (0.39)
Teacher race ethnicity (not white)	0.42
Teacher years of education	16.86 (1.60)
Teacher years of experience	15.68 (9.73)
Proportion of classroom	
Boys	0.51
Limited English Proficiency	0.56
Minority	0.77
Mean classroom-level income-to-needs ratio	0.88 (0.29)
Class size	16.86 (1.85)
Classroom type	
Head Start	0.23
Private center	0.15
Public school	0.62

Notes. Estimates may not sum to 1.00 due to rounding. Estimates correspond to means or proportions and estimates in parentheses correspond to standard deviations. Classroom and teacher descriptives were generated at the classroom and teacher level, not at the child level.

For socioemotional development (Table 4), more classroom time spent on academic instruction was associated with lower teacher-reported closeness ($ES = -0.13$), task orientation ($ES = -0.10$), and social skills ($ES = -0.15$), in addition to higher teacher-reported conflict ($ES = 0.12$). Conversely, higher quality observed teacher-child interactions predicted lower teacher-reported conflict ($ES = -0.08$) while higher level (more rigorous) math instruction was associated with higher social skills (ES = 0.14). At the same time, however, children who spent more time in routines in contrast to free play exhibited higher conflict ($ES = 0.12$) and conduct problems ($ES = 0.08$).

Examining children's executive functioning (Table 5), analyses indicated a positive association between higher quality teacher-child interactions and greater working memory (backwards digit span; $ES = 0.06$). Moreover, more time of class time focused on academic topics was (counterintuitively) associated with lower inhibitory control (pencil tap; $ES = -0.06$).

Heterogeneity in classroom effects

Once the main effects of classroom process factors were examined, we then examined the extent to which associations between classroom process factors and child outcomes were moderated by children's fall

Table 2
Descriptive statistics for the child outcomes.

	Mean or % (SD)	ICC
Academic outcomes		
Letter-Word Identification (fall)	317.05 (29.95)	
Letter-Word Identification (spring)	341.26 (28.18)	0.05
Picture Vocabulary (fall)	440.76 (24.60)	
Picture Vocabulary (spring)	453.66 (16.32)	0.12
Applied Problems (fall)	380.55 (31.90)	
Applied Problems (spring)	403.28 (23.54)	0.05
Quantitative Concepts (fall)	405.62 (14.84)	
Quantitative Concepts (spring)	418.98 (16.77)	0.06
Social-behavioral outcomes		
Closeness (fall)	4.04 (0.87)	
Closeness (spring)	4.33 (0.74)	0.24
Conflict (fall)	1.58 (0.88)	
Conflict (spring)	1.55 (0.82)	0.15
Frustration tolerance (fall)	3.25 (0.94)	
Frustration tolerance (spring)	3.39 (1.00)	0.30
Task orientation (fall)	3.44 (0.92)	
Task orientation (spring)	3.67 (0.96)	0.17
Social skills (fall)	3.85 (0.86)	
Social skills (spring)	4.08 (0.85)	0.26
Conduct problems (fall)	1.84 (0.93)	
Conduct problems (spring)	1.79 (0.91)	0.14
Executive function outcomes		
Backward Digit Span Task (fall)	1.18 (0.52)	
Backward Digit Span Task (spring)	1.42 (0.76)	0.00
Head, Toes, Knees, Shoulders Task (fall)	14.91 (22.43)	
Head, Toes, Knees, Shoulders Task (spring)	30.86 (27.75)	0.03
Pencil Tap (fall)	7.77 (5.57)	
Pencil Tap (spring)	11.41 (5.00)	0.02

Notes. Estimates correspond to means and those in parentheses correspond to standard deviations.

scores on the measures, child poverty (income to needs ratio), and children's home language (English, Spanish, or other). Of the 200+ interactions tested, only 18 were significant at the $p < .05$ level. Because these interactions were not consistent and we would expect as much by chance, they were not included in further interpretation.

Discussion

Despite the widespread adoption and implementation of publicly funded early education programs for 4-year-olds, now underway for almost 20 years, there remain a host of gaps in our knowledge about how to best implement these programs so that children receive the most beneficial experience (Barnett et al., 2018; Phillips et al., 2017; Yoshikawa et al., 2013). During this decades-long expansion, to the point at which for most low-income children school begins at age 4, evaluations of whether pre-K "works" have been a major focus of research, often yielding mixed results (e.g., Barnett et al., 2018; Bloom & Weiland, 2015; Lipsey et al., 2018; Magnuson et al., 2007; Puma et al., 2012; Weiland & Yoshikawa, 2013). These mixed results, whether null, positive, or even negative, are most often explained by inferred experiences of children in classrooms – including factors often bundled under the broad frame of "classroom quality," which often includes features of teachers' behavior with children (e.g., interaction, instructional behaviors, etc.), implementation of curricula of various forms, professional development supporting teachers' instruction, and teachers' differentiation of instruction, to name a few (Barnett et al., 2018; Burchinal et al., 2016; Keys et al., 2013). Unfortunately our knowledge about these (and other) classroom processes is incomplete and evidence suggests mixed results on their impacts on children's learning (Ansari & Gershoff, 2015; Bratsch-Hines, Burchinal, Peisner-Feinberg, & Franco, 2019; Burchinal et al., 2016; Chien et al., 2010; Lippard, Choi, & Walter, 2019), with most studies indicating effect sizes, when positive, as small.

The present study, an early report from a longitudinal study of classroom processes and child outcomes, reports on associations between several malleable features of directly-observed classroom processes and children's school readiness skills across the pre-K year. Notably, the multiple forms of classroom process—teacher-student interaction; dosage, rigor and content of instruction—were all evaluated for their unique and interactive associations with learning and development. We find evidence for the separate, and (for some outcomes) additive, relations of each of these classroom process features with children's skills: overall quality of teacher-student interaction, teachers' direct involvement in educational activities, the rigor of those activities in terms of difficulty, and children's exposure to academic content. However, the positive associations between classroom processes and children's skill levels across the year were not widespread or large, with magnitudes ranging from 5 to 15% of a standard deviation. In models in which multiple classroom process features demonstrated significant associations with a particular outcome, their combined effect sizes approached 20% of a standard deviation. As a general pattern, children's performance appeared modestly greater when classrooms were more educationally focused and structured, and teachers were supportive and responsive as they were involved with children.

We note again that these findings are modest in terms of reflecting the possible associations between classroom features and children's

Table 3
Associations between classroom processes and children's academic outcomes.

	WJ1 - Letter/Word Identification		WJ10 - Applied Problems		WJ14 - Picture Vocabulary		WJ18 - Quantitative Concepts	
Child Characteristics	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Fall skill	19.23***	0.95	15.30 ***	0.74	12.10***	0.59	11.69***	0.36
Income to needs ratio	0.75	0.61	1.83***	0.56	0.17	0.39	1.05**	0.36
Home lang = Spanish	−0.87	2.33	0.53	2.12	−3.06**	1.00	−0.74	1.22
Home lang = Other	6.76 ***	1.52	2.15	1.43	−1.22	0.77	1.37	1.14
Classroom processes								
Teacher-Child Intx.	1.16	0.68	1.37 *	0.59	0.56	0.52	1.76***	0.45
Proportion academics	0.69	1.02	−0.31	0.69	−0.52	0.55	0.46	0.60
Proportion tchr-struc	2.62 *	1.03	0.05	0.76	0.47	0.59	0.53	0.53
Proportion routines	2.58 *	1.19	0.31	0.82	1.14	0.60	1.05	0.65
Literacy rigor	0.42	1.41	0.01	0.92	0.25	0.77	−0.29	0.79
Math rigor	−0.93	1.17	−0.74	0.69	−0.38	0.56	−0.28	0.71

Home lang = Home language; Teacher-child intx = teacher-child interactions; Proportion tchr-struc = proportion teacher structured. All continuous predictors were standardized to have a mean of 0 and standard deviation of 1.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 4
Associations between classroom processes and children's social-emotional outcomes.

	Closeness		Conflict		Frustration tolerance		Task orientation		Social skills		Conduct problems	
Child Characteristics	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Fall skill	0.45***	0.03	0.57***	0.03	0.64***	0.03	0.68***	0.03	0.54***	0.03	0.65***	0.03
Income to needs ratio	−0.00	0.02	0.01	0.02	0.01	0.03	0.01	0.02	−0.01	0.02	−0.01	0.02
Home lang = Spanish	−0.14*	0.06	−0.11	0.08	0.15	0.08	0.01	0.08	0.02	0.07	−0.05	0.08
Home lang = Other	0.08	0.05	−0.10	0.05	0.03	0.06	0.02	0.05	0.09	0.06	−0.09	0.06
Classroom Processes												
Teacher-Child Intx.	0.06	0.04	−0.06*	0.03	0.05	0.06	0.06	0.05	0.04	0.05	−0.05	0.04
Proportion academics	−0.09**	0.04	0.10***	0.03	−0.09	0.05	−0.10*	0.04	−0.12**	0.04	0.02	0.03
Proportion tchr-struc	0.01	0.04	−0.05	0.04	0.07	0.07	−0.03	0.05	0.05	0.05	−0.03	0.04
Proportion routines	−0.01	0.05	0.10**	0.04	−0.04	0.08	−0.10	0.06	−0.01	0.06	0.08*	0.04
Literacy rigor	0.02	0.05	−0.01	0.04	−0.03	0.08	0.00	0.07	−0.05	0.05	−0.04	0.05
Math rigor	0.01	0.05	−0.01	0.04	0.10	0.07	0.07	0.06	0.12*	0.06	0.02	0.04

Home lang = Home language; Teacher-child intx = teacher-child interactions; Proportion tchr-struc = proportion teacher structured. All continuous predictors were standardized to have a mean of 0 and standard deviation of 1. Closeness and Conflict from STRS; others from TCRS.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

learning gains and that they are somewhat inconsistent across outcomes and processes. However, as a way of contextualizing these findings, consider that several large-scale investigations of the effects of schooling on children's learning report the overall increment for schooling effects to be not much larger than 30% of a standard deviation. Thus, the findings reported herein suggest that these classroom process features collectively may account for about half or more of the marginal increment in prediction of children's learning attributable to schooling (Nye et al., 2004; Pianta, Mashburn, et al., 2008.

Of the possible mechanisms of pre-K program effects (above and beyond children's initial skill level and a large number of teacher, child, and classroom factors), children's directly-assessed academic skills were greater when teachers were involved with children in an instructional activity and when children were exposed to routines and activities with academic content (for literacy skills), or to higher quality teacher-student interaction (for applied problems and quantitative concepts). In the area of executive functioning, exposure to higher-quality interactions with teachers over the course of the year was also predictive of greater levels of children's working memory skills. Notably, these associations were independent of one another, suggesting the possible value of a package of factors reflective of the classroom as an educationally focused setting, balancing structure and exposure to instructional activity with responsive engagement by the teacher.

When interpreting teachers' reports of children's social adjustment in the classroom as associated with observed and reported classroom process, the interdependent nature of classroom inputs and teachers' views becomes a consideration. For example, teachers reported lower levels of children's task orientation and social skills along with lower closeness and higher conflict with children when they spent more time in structured academic instruction. This may be a consequence of children's attention and capacity for engagement diminishing when academic activities went longer, or alternatively, teachers may provide more instruction when they perceive that students are less likely to be attentive. Additionally, when teachers reported using instructional practices that exposed children to more difficult academic content, they also described their students as showing higher levels of social skills, on average. Again, it is not clear whether teachers drew from more difficult content as a result of their view that students' were well adjusted, or that such content was helpful to the development of those skills. And when teachers were observed to show more responsive interactions with students, not surprisingly, they reported less conflict with their students. In all these instances, it is not possible to disentangle the nature of the associations between teachers' views of children's competencies from teachers' practices in the classroom.

A notable aspect of these results is contained in the preliminary analyses and results for the baseline predictors, specifically, the very

Table 5
Associations between classroom processes and children's executive functioning skills.

	Backward digits span		Head toes knees shoulders		Pencil tap	
Child characteristics	*b*	*SE*	*b*	*SE*	*b*	*SE*
Fall skill	0.26***	0.04**	13.95***	0.80	2.27***	0.15
Income to needs ratio	0.05	0.02	0.90	0.63	0.25	0.14
Home lang = Spanish	0.04	0.09	6.75*	3.25	−0.19	0.49
Home lang = Other	−0.02	0.08	−2.61	2.62	−0.49	0.37
Classroom processes						
Teacher-Child Intx.	0.05*	0.02	1.15	0.81	−0.15	0.15
Proportion academics	−0.01	0.03	−1.27	0.97	−0.32*	0.15
Proportion tchr-struc	0.01	0.03	−0.15	0.76	0.02	0.22
Proportion routines	0.01	0.03	−1.05	0.90	0.04	0.21
Literacy rigor	−0.04	0.02	−1.49	0.96	−0.10	0.17
Math rigor	0.00	0.02	0.15	0.95	0.08	0.17

Home lang = Home language; Teacher-child intx = teacher-child interactions; Proportion tchr-struc = proportion teacher structured. All continuous predictors were standardized to have a mean of 0 and standard deviation of 1.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

large influence of individual differences between children in accounting for gains over time in their skills. More specifically, the intraclass correlations coefficients for the child-level direct assessments were far and away much larger than those for the observations of classroom-level processes. In other words, children's skills and abilities as they entered pre-K were by far the most important determinant of where they ended up in spring. Perhaps not surprisingly, the strongest predictors of children's spring skills were their fall scores on the corresponding assessment and the child's age at the time of assessment.

Finally, when we examined heterogeneity in the aforementioned associations, there was only chance evidence that classroom processes mattered more (or less) as a function of children's family income or DLL status, both of which figure prominently in discussions of eligibility and access for pre-K. We also found little to no evidence of variation in program effects as a function of children's pre-K entry skills. Although somewhat surprising, these results may be a function of a truncation in range with regard to the family background features for these children who were already enrolled in pre-K designed to target children from low income or dual language households. That is, oftentimes in studies that consider heterogeneity in program effects there are more advantaged children as a point of reference, which was not the case in our study and, thus, limits the comparisons we could make. What the lack of moderation effects does suggest is that better classroom processes and higher levels of children's readiness skills are associated similarly across groups that differ on demographics or skills; in other words, these classroom resources may benefit all children equally.

Despite its possible contributions to the literature, the current study has a number of limitations that require attention. Primarily, the design of the current investigation was not experimental; children were not assigned randomly to pre-K classrooms that varied systematically on the features of classroom processes that are the focus of the present study. At the same time, however, the use of lagged dependent variables, which is recognized as one of the strongest adjustments for omitted variable bias (Early Child Care Research Network & Duncan, 2003), lends greater confidence to our findings. Moreover, the results reported herein do not reflect the wide range of pre-K programs in operation across the country; it is a study of a single county's efforts and so there may be important variation in organizational and program structures and types, as well as classroom process features that are not reflected. Consequently, the conclusions are not widely generalizable. Also, it is important to mention that the outcome assessment(s) chosen for this evaluation do not map directly onto the curricula in use within these programs or the instructional focus at the classroom level. As such, the use of these assessments may obscure program effects (benefits or losses) that might be detected if the assessments used were more proximal to children's classroom experiences and aligned directly to the curricular and instructional focus of the program. Lastly, our results make use of child direct assessments that were administered in English, despite the fact that many participants spoke a language other than English at home, often Spanish. The linguistic diversity of this program meant that it was necessary to assess children in a common language. We note, though, that even for dual language learners who are learning English, early academic skills assessed in English are important predictors of children's achievement in elementary school (e.g., Fitzgerald, Amendum, Relyea, & Garcia, 2015). Future research in Spanish/English DLL populations should seek to replicate the findings using Spanish and English achievement batteries.

In sum, the results of the present study confirm that preschool classrooms that are more educationally focused, in which teachers are responsive and stimulating in their interactions and provide numerous opportunities for children to engage with academic content, are those classrooms in which children are likely to learn more. Results also suggest that these features of classroom process may function as a package of educational resources that each contribute to learning. However, the magnitude of these features of classroom process, in terms of relations with children's learning, pale in comparison to the skill level children demonstrate as they enter pre-K, confirming the central importance of prior experiences in the birth – age 3 period (Ansari, Pianta, Whittaker, Vitiello, & Ruzek, 2019). Despite the modest magnitude of associations between classroom processes and children's learning during the pre-K year, the results provide support for continued efforts to improve classrooms' capacity in terms of curriculum, instruction, and qualities of teachers' interactions with children.

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