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Mazzocco, Michele M.	University of Minnesota	0000-0001-5209-3550
Burchinal, Margaret R.	University of Virginia	0000-0002-3606-7843
Schulte, Ann C.	North Carolina State University	0000-0002-8035-9464
Vandell, Deborah L.	University of California, Irvine	0000-0003-2373-9783
Sanabria, Ashley	San Diego State University	0000-0002-9960-3199
Hwang, Jin Kyoung	University of California, Irvine	0000-0003-3074-8047

Publication/Completion Date—(if *In Press,* enter year accepted or completed) June 2024

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Early Childhood Research Quarterly, 69, 25-37

DOI or URL to published work (if available) https://doi.org/10.1016/j.ecresq.2024.04.007

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Mathematics in U.S. Preschool and Kindergarten Classrooms

Michèle M. Mazzocco [1,a], Margaret R. Burchinal [2], Ann C. Schulte [3], Deborah Lowe Vandell [4], Ashley Sanabria [4,b], Jin Kyoung Hwang [4], Carol McDonald Connor [4,c]

[1] University of Minnesota, Institute of Child Development, 51 East River Parkway, Minneapolis, MN 55455 USA

[2] University of North Carolina, Chapel Hill; 515 Oak Crest Drive, Chapel Hill, NC 27516 USA

[3] North Carolina State University; Department of Psychology, 640 Poe Hall, CB 7801 Raleigh, NC 27695-7801 USA

[4] University of California, Irvine; School of Education, 2050 Education Building, Irvine, CA 92697 USA

[a] Corresponding author

[b] Ashley Sanabria is now at School of Speech, Language, and Hearing Sciences, San Diego State University.

[c] Posthumous authorship, original principal investigator.

Acknowledgments

We are most grateful to all the sites in the Institute of Education Sciences (IES) Early Learning Network (MDRC, Ohio State University, University of California-Irvine, University of Nebraska, University of North Carolina - Chapel Hill, University of Virginia) for recruiting the schools and classrooms for this study and collecting the videotaped classroom observations. This study would not have been possible without them. The authors also thank the teachers and students in participating classrooms and research assistants across study sites involved in the research.

Declaration of Conflicts: Dr. Carol Connor had an equity interest in Learning Ovations, a company that has since been acquired by Scholastic and which may potentially benefit from the research results using OLOS. The terms of this arrangement were reviewed and approved by the University of California, Irvine in accordance with its Conflict of Interest policies. Dr. Ann Schulte was a consultant for Learning Ovations. All remaining authors have no conflicts to declare.

Authorship Statement

M. Mazzocco: Conceptualization, Methodology, Writing – Original Draft, Writing – Review & Editing. **M. Burchinal**: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing. **A. Schulte**: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing. **D. Vandell**: Conceptualization, Methodology, Data Curation, Supervision, Project Administration; Writing – Original Draft, Writing – Review & Editing, Funding Acquisition. **A. Sanabria**: Project Administration, OLOS Methodology and Resources, Investigation, Data Curation, Validation, Writing - review & editing. **JK. Hwang**: OLOS Resources, Investigation, Data Curation, Writing - Review & Editing. **C.M. Connor**: Investigation, Methodology, Resources, Software, Supervision, Validation, Funding Acquisition.

Funding: This work was supported by the Institute of Education Sciences (IES) [Grant Number R305N160050] awarded to Carol Connor and Grant Number R305N160013 awarded to Deborah Lowe Vandell] for a project entitled, *Research Networks Focused on Critical Problems of Education Policy and Practice.* This work is a component of the *Supporting Early Learning from Preschool through Early Elementary School Grades Network*, commonly referred to as *The IES Early Learning Network.*

Abstract

To provide a landscape of mathematics activities children experience in U.S. preschool and kindergarten classrooms, we observed time children spent in mathematics activities (and — as a contrast — literacy) in 101 geographically diverse early childhood classrooms in seven U.S. states. We also observed what mathematics content, grouping strategies, and management formats teachers engaged during classroom mathematics activities. Each observation lasted approximately 2 hours; collectively these observations focused on 930 children observed one to three times during the 2018/2019 or 2019/2020 school year. Averaging across individuals' data within classrooms, we found that mathematics and literacy activities comprised 5% and 45% of time observed in preschool classrooms, respectively; and 26% and 42% of time observed in kindergarten classrooms, respectively. At both grades, when mathematics activities occurred, they were proportionally more often teacher-led rather than child-led. These findings raise concerns about the paucity of mathematics and over-reliance on developmentally inappropriate teacher-managed mathematics instruction in early childhood classrooms, especially preschools. Amount of time in math did not vary by preschool auspice, but time in literacy and the proportion of math time devoted to specific math content did: In Head Start classrooms we observed lowest percentage of time in literacy (and the highest percentage of time in non-instruction) compared to all other auspices. Across auspices, numeracy was the predominant math content area overall, but especially in Head Start classrooms. Thus, some aspects of early mathematics may differ with program auspice, suggesting that recommendations to increase and improve early mathematics activities may need to consider auspice characteristics.

Keywords: Mathematics, preschool, kindergarten, classroom observations

Mathematics in U.S. Preschool and Kindergarten Classrooms

Research makes clear that a child's knowledge and skills in early mathematics are related to their mathematics achievement throughout their school years (e.g., Geary et al., 2013). These associations emerge from studies of typically achieving students (e.g., Duncan et al., 2007), precocious math learners (e.g., Hoard et al., 2008), and children with mathematics learning difficulties (e.g., Jordan et al., 2009; Judge & Watson, 2011). It also is clear that individuals who lack strong foundational mathematics skills at kindergarten are at higher risk for not achieving mathematics proficiency throughout their schooling (e.g., Judge & Watson, 2011; Mazzocco & Thompson, 2005), although many factors contribute to struggles with mathematics (e.g., Berch & Mazzocco, 2007). Regardless of the underlying nature of the association between early and later mathematics, an understanding of which factors contribute to variation in children's early mathematics skills may support efforts to increase the proportion of young children who establish sound foundational mathematics skills during, or even prior to, kindergarten.

One potential source of variation in early mathematics skills concerns the *amount* and *types* of mathematics learning opportunities children experience in preschool and kindergarten classrooms. Identifying how those opportunities vary along these two dimensions may inform subsequent causal studies of how early formal instruction impacts mathematics achievement outcomes. Accordingly, in the present study we aim to describe and quantify the nature of mathematics learning opportunities children experience among a geographically diverse sample of preschool and kindergarten classrooms in the U.S. Given the wide range of preschool programs that exist, we also explore if the variation observed in preschool classrooms systematically is linked to program auspice, or funding source. Though focused on descriptive and correlational relations, this study offers insights into the mathematics learning opportunities children experience during the earliest of school years.

Why Study Mathematics in Preschool and Kindergarten Classrooms?

Researchers have shown that, on average, an individual's mathematics achievement level persists over time. For example, children who scored in the below average to deficient range on Kindergarten or Grade 1 mathematics achievement tests were significantly more likely to underperform on various aspects of mathematics two (Jordan et al., 2010), four (Murphy et al., 2007), or even nine years later (Geary et al., 2013) compared to typically achieving peers. These studies collectively link mathematics skills from primary school to adolescence (e.g., Geary et al., 2013; Geary & VanMarle, 2016). Awareness of these trajectories is of growing interest to policy makers throughout the world (e.g., Cross et al., 2009; Education Endowment Foundation, 2022; Ginsburg, Lee, & Boyd, 2008; Lehrl et al., 2016) who aim to identify strategies to support early and thus ongoing successful mathematics achievement. The motivation for this interest is straightforward: If trajectories for persistently low achieving students can be modified (and then sustained) in early education, mathematics outcomes may improve (Watts et al., 2017, 2018).

It is unclear what precise roles early childhood classrooms may play in establishing or altering mathematics achievement trajectories, and what factors underlie those roles. Any study of these potential roles benefits from knowing how early childhood classrooms vary with respect to their mathematics learning opportunities. Therefore, we aim to identify what early mathematics activities typically occur in preschool and kindergarten classrooms and what principal sources of variation emerge among these early math activities. This knowledge is essential given high rates of preschool and kindergarten attendance. In the U.S., many children attend a preschool program before they enter kindergarten. For instance, in 2019, over 60% of all

4-year-olds in the U.S. enrolled in a preschool program (Cascio, 2021). (We note that these rates reflect pre-pandemic averages and represent the period during which our study occurred.) These preschoolers attended a wide range of program types, including private community-based programs run through private organizations, federally subsidized Head Start programs, and locally- or state-funded prekindergarten (pre-K) programs (McElrath & Bauman, 2021). In the present study our participating classrooms reflected these notable variations in preschool programs available within the U.S.

Preschool programs vary in terms of their purpose and goals (Burchinal, 2023). Community-based organization (CBO) childcare evolved to provide working parents with a safe childcare setting for their children, although these programs may also focus on promoting academic skills to attract clientele. Head Start is a federally funded program initiated in 1965 as part of poverty reduction legislation (i.e., the Economic Opportunity Act, 1964) also referred to as the War on Poverty. Despite a focus on promoting academic skills, Head Start's primary focus is on the "whole child" (e.g., Office of Head Start, 2021), so it offers a comprehensive program that focuses on supporting health, nutrition, parent engagement, and social services to low-income families with young children. By contrast, public pre-kindergarten (pre-K) programs began in 1972 to specifically promote academic skills among preschoolers, many of whom are low income. Many pre-K programs provide funding for classrooms in public schools and funding for enrollment slots in Head Start or community programs that meet eligibility standards (see Burchinal, 2023 for a more detailed review). All three types of preschool classrooms are represented in the present study, although aspects of children's classroom experiences are likely to vary with program auspice.

Although our study focuses on preschool and kindergarten classrooms in the U.S., we acknowledge that preschool and kindergarten enrollment rates are high also internationally, though highly variable. For instance, among 49 OECD countries included in a review of preschool attendance, attendance among 4-year-olds ranged from about 10% (Saudi Arabia) to nearly 100% (for 13 European countries; OECD, 2023). In the U.S., kindergarten enrollment is higher relative to preschool, in part because of compulsory attendance laws in 19 of 50 states. Still, kindergarten attendance is high even in states where it is not mandatory (Education Commission of the States, 2020). Among all kindergarten enrollees, 84% attend a public government-supported kindergarten program (typically in a public elementary school), and 16% attend a private school (U.S. Census, 2022). These high rates of enrollment raise the importance of knowing what mathematics activities occur in preschool and kindergarten classrooms.

The Nature of Early Mathematics Learning Opportunities

Based on prior research, we anticipated that children would experience limited opportunities for mathematics activities in their preschool and kindergarten classrooms. In one observational study conducted in European and U.S. preschools, researchers found that mathematics-focused activities occurred during only 3%-6% of their observational times on average, with little variability in average frequencies across countries (Sweden, Portugal, U.S.) despite wide variation across individual classrooms (Coelho et al., 2021). A large multi-state study of U.S. pre-K programs similarly reported that children spent an average of 6%-8% of their morning time in math instruction (Howes et al., 2008). This finding is not surprising given that popular preschool curricula used in the U.S. put relatively little emphasis on mathematics compared to other topic areas such as literacy (Claessens et al., 2021), excepting the very few curricula focused solely or predominantly on mathematics (e.g., Building Blocks; Sarama &

Clements, 2004). This limited focus of mathematics in preschool may be consequential, given the causal evidence that more exposure to mathematics in preschool is linked with stronger mathematics performance at Grade 5 (at about age 10 years), albeit with inconsistent and sometimes small effect sizes (Watts et al., 2017) that vary with instructional factors (Wang et al., 2016) and other factors, such as children's home mathematics experiences (e.g., Sonnenschein & Galindo, 2015). In the present study, we extend these findings by observing how much time children spend in mathematics activities in both preschool and kindergarten classrooms and assessing differences across these two early periods of schooling. The mathematics learning opportunities we observed range from teacher-managed formal instruction to more informal child-managed learning opportunities such as center-based play focused on mathematics content. We focused on the mathematics learning opportunities children encountered, rather than exclusively observing teachers' behaviors or relying on teachers' self-report.

Mathematics Content in Early Childhood Classrooms

Rather than limit our descriptive study to how *much* mathematics is observed in early childhood classrooms, we considered that very few studies to date have focused on what specific mathematics *content* is observed in preschool or kindergarten classrooms or directly compared mathematics content across these two grades. Researchers who have pursued this work to date have, for the most part, relied on reports from preschool or kindergarten teachers. For instance, Engel and colleagues (2013; 2016) found that kindergarten instruction in the U.S. is focused primarily on *basic* mathematics principles that many kindergartners have already attained rather than on advancing mathematics skills across multiple and novel mathematical domains. In an expansion on these findings, researchers found substantial overlap in preschool and kindergarten teachers' reports of instructional focus: Approximately 37% of kindergarten teachers' mathematics instruction overlapped with mathematics that was covered in preschool instruction, and this instructional redundancy pertained to basic rather than advanced skills (Cohen-Vogel et al., 2021). These trends vary across countries, at least in preschool: Li and colleagues (2015) found that an emphasis on teaching basic math skills – specifically counting, shape identification, and unidimensional sorting – was more commonly reported by preschool teachers in the U.S. compared to preschool teachers in China, who in turn reported focusing on more advanced principles such as operations, classifying geometric attributions, and multidimensional sorting. Perhaps this partially explains why only 5% of kindergartners in one U.S. study (Engel et al., 2013) had age-appropriate mastery of operation skills in kindergarten.

Mathematics content observed in preschool classrooms may reflect the instructional resources available to early childhood educators, such as curricula. Although specific preschool mathematics curricula do exist (e.g., Building Blocks, Sarama & Clements, 2004; Big Math for Little Kids, Ginsburg et al., 2003), most preschool programs rely on general curricula that vary with respect to their inclusion of mathematics activities. In their review of general preschool curricula that are widely adopted in U.S. preschool programs, Claessens and colleagues (2021) found that mathematics activities comprise about 4%-37% of all activities per curriculum, with a median of 13.6%. One shared feature of these curricula is their specific focus on numbers and counting and at least some content in one or more additional mathematics domains such as geometry, operations, or patterning. On the surface, this seems encouraging; but most curricula *predominately* focused on numbers and counting (comprising 24%-60% of all mathematics activities within a curriculum), consistent with prior teacher reports (Engels et al., 2013).

Numbers and counting are age-appropriate content for preschoolers and kindergartners, but many preschool and kindergarten teachers may overemphasize basic number knowledge skills at the expense of omitting advanced number skills and other mathematics domains, as summarized previously (Engel et al., 2013). For example, geometry concepts such as shape and spatial perception are as important as number concepts in early childhood mathematics (e.g., Sarama & Clements, 2009), and patterning skills – such as identifying, replicating, and extending patterns – are foundational to algebraic thinking (e.g., Fyfe et al., 2017). Yet both geometry and patterning were underrepresented in most preschool curricula (Claessens et al., 2021). This is unfortunate because patterning knowledge is linked to pattern detection in other areas of mathematics, such as arithmetic calculation (Fyfe et al., 2017; MacKay & de Smedt, 2019). Like patterning, measurement skills cut across the primary areas of numbers and geometry, because children rely on numerical or spatial concepts to evaluate length, volume, and even abstract concepts such as time and money. In all but one of the curricula reviewed by Claessens and colleagues (2021), measurement skills were surpassed by number and counting activities. Some of the curricula focused predominantly on measurement or operations, but none focused predominantly on geometry. In the present study, we examined what specific mathematics content children are exposed to in preschool and kindergarten classrooms and if number knowledge was the predominant focus of mathematics instruction relative to other domains, consistent with teacher reports and curricula review. Given the lack of uniformity in mathematics domains across popular early curricula, we expected much variability in the relative focus on math domains observed in these classrooms.

Dimensions of Instructional Contexts: Grouping Strategies, Management Formats

Exposure to early mathematics is no guarantee of short- or long-term benefits (Watts et al., 2017), so it is important to consider additional aspects of early mathematics that may influence potential benefits. In this study, we considered two dimensions by which early mathematics activities may vary above and beyond time and mathematics content: grouping strategies (e.g., large or small group activities) and management format (i.e., teacher- or student-managed activities). These dimensions matter in part because they affect children's classroom experiences. Wang and colleagues (2016) examined the relation between student grouping strategies and mathematics performance in their meta-analysis of 29 preschool mathematics intervention studies. They found that, on average, effect sizes were smallest for interventions delivered via whole group (based on 10 studies) compared to small group (n=14 studies) or individualized instruction (n=5 studies), and largest for the latter; there were, however, no significant pairwise differences across grouping strategies owing to wide heterogeneity of effect sizes (and small number of studies) per grouping strategy (Wang et al., 2016). Nevertheless, these findings suggest that grouping strategies may matter for mathematics instruction. Similarly, attention to teacher- versus student-managed instructional formats has informed improvements in early childhood reading instruction: Connor and colleagues (2007) found that first graders' gains in reading scores were at least partially related to the interaction between the relative proportion of time children's instruction focused on reading comprehension or on phonics (content) and the proportion of time instruction was managed by a teacher vs. by students (in peer groups or alone).

Wang and colleagues (2016) also examined the effect of time engaged in a mathematics intervention on student gains in mathematics and found that more time per week was associated with larger effect sizes, if time was examined continuously. When discrete time intervals were compared, none differed significantly from the others, given the variation in effect sizes for each interval. Thus, more time may be better overall, but the relation is nonlinear; efficacy depends on other factors, such as context. This notion is aligned with child by instruction interactions reported for literacy (e.g., Connor et al., 2007) and mathematics (e.g., Connor et al., 2018).

Considered together, the studies reviewed thus far demonstrate that mathematics content varies in early childhood curricula and interventions, even if most activities focus on number knowledge rather than other mathematics domains. Studies also show that factors related to the contextual dimensions of mathematics instruction may vary across classrooms. Before researchers can assess *whether* any of these variables may influence the trajectory of mathematics skills and achievement, it is essential to first describe whether these factors vary within and across preschool and kindergarten classrooms. In other words, any attempt to comprehensively depict the landscape of early mathematics learning opportunities in preschool and kindergarten must attend to factors that have the potential to inform early mathematics instruction efficacy. Accordingly, in the present study, we quantified the time children were exposed to mathematics instruction; and observed instructional content, grouping strategies, and the extent to which activities were teacher- or student-managed.

Our observational study of preschool and kindergarten may build upon the reported instructional shifts in academic expectations as reported by preschool and kindergarten teachers (Bassok et al., 2016). For instance, compared to teacher-reported data from 1998, data from a 2010 survey of kindergarten teachers showed higher expectations for early reading and math skills at kindergarten entry, more time devoted to reading and math instruction, and a relatively larger proportion of teacher-led instruction. But to date, few if any studies have directly observed how math is taught in preschool and kindergarten or across different preschool programs.

The Current Study

In the present study, we report on observational data collected in 104 preschool and kindergarten classrooms, using an observational system designed to support our principal aim: To pursue a comprehensive descriptive analysis of mathematics learning opportunities across preschool and kindergarten classrooms. To achieve these aims, we conducted multiple observations per classroom, for about two hours per visit.

Primary Research Questions 1 and 2

To maximize our ability to both describe and compare early mathematics experiences in U.S. preschool and kindergarten classrooms, our aim was to specify the nature of children's experiences in terms of the *content* to which children are exposed and the instructional *contexts* through which this exposure occurs. Accordingly, for Research Question 1 we asked how *much* mathematics instruction children received in preschool and kindergarten classrooms and to what *kinds* of mathematics content children were exposed. To pursue these questions, we measured average time spent in mathematics instruction in minutes per classroom, for preschool and kindergarten, cross-sectionally; both in the aggregate and in terms of proportions of mathematics instruction devoted to the specific mathematics content domains of number knowledge, operations, algebra (patterning), geometry, and applied mathematics. To provide a meaningful contrast, we also measured time spent on literacy instruction related to both research questions.

Informed by prior research, for Research Question 1 we hypothesized that mathematics activities would comprise relatively brief proportions of the total classroom observation period, relative to literacy. We also predicted greater time devoted to number knowledge relative to other mathematics domains, with overlap in number knowledge instruction across the two grades examined; and large variability in what mathematics domains are observed across classrooms, particularly in preschool. Across-grade comparisons were of particular interest given the large (and increasing) rate of preschool enrollment throughout the U.S. and internationally, and the relatively limited research that affords direct comparison of mathematics instruction across preschool and kindergarten at the same time in history.

For Research Question 2, we asked what grouping strategies and management formats children experienced (e.g., teacher- or student-led) during mathematics activities. We did not have directional hypotheses for this descriptive aim, as our goal was to describe what variation exists given the potential importance of instructional context for early mathematics.

Research Question 3

In view of the range of preschool programs among participating classrooms, we explored whether the variation to emerge from Research Questions 1 and 2 was systematically related to program auspice. This aim was relevant to preschool classrooms only, given the wide range of preschool programs that children may attend. Thus this was an exploratory aim, not an intentional focus of the original research design. Although we did not have directional hypotheses, we anticipated that differences were likely because programmatic goals vary across auspice. For instance, public pre-K programs focus on promoting academic skills, Head Start programs focus on the whole child (academic, cognitive, social skills), and a focus of community-based centers is to support working parents (Burchinal, 2023).

Method

Participants

This research was reviewed and approved by the Human Subjects Institutional Review Board (IRB) at each collaborating data collection sites (California, Massachusetts, Nebraska, North Carolina, Ohio, Virginia). These state-level sites were selected by peer review as part of a multi-site grant funding competition. Within each data collection site, the individual preschool and kindergarten sites were convenience samples, recruited by flyers, emails, and outreach to centers and schools with existing community relationships at each site. As per IRB approved protocols at select sites, observations were limited to children whose parents completed and returned consent forms. In this study, we limited our analysis to classrooms for which we were able to observe at least 3 children, and to individuals who were in their classroom for at least 40 minutes. We excluded three kindergarten classrooms in private schools or childcare centers because the vast majority of classrooms were publicly funded. Across all sites, the final sample consisted of 101 classrooms (77 preschool and 24 kindergarten) recruited across all seven states (the California site also recruited schools in Arizona).

Three auspices emerged among preschool classrooms: There were 18 Head Start classrooms, 43 community-based organization (CBO) preschools, and 16 pre-K programs of which nine were located within public schools. By contrast all 24 of the kindergarten classrooms included in the study were in publicly funded schools. Table S1 (Supplemental Information) provides a summary of the characteristics of 929 of the 930 children (716 preschool and 213 kindergarten) attending these classrooms. (Demographic data were missing for one preschooler.) The top half of Table S1 summarizes these child characteristics at the classroom level. The bottom half of Table S1 summarizes these characteristics for individual children. The Head Start classrooms included proportionally more children of color and children who spoke a language other than English, relative to other program types.

Among all classrooms, 68% of participating teachers completed a report of professional experience. Among these teachers, 74% had a bachelor's degree, 20% had a master's degree, and 6% had an A.A. degree. Years of early childhood teaching experience ranged from one to 36 years among teachers who completed the self-report. These percentages were consistent/varied across preschool auspice and kindergarten, as follows.

The distribution of teachers by highest degree differed somewhat across auspice. Among those teachers who completed the self-report, we observed three notable patterns. First, the relatively few teachers reporting an AA as their highest degree earned were teachers in Head Start or CBO preschool classrooms only, where they comprised 25% and 18% of all teachers in those two settings, respectively. Second, across all three preschool auspices and kindergarten, more than half of teachers (63%-78%) had a bachelor's degree. Third, teachers with a master's degree were in all settings except Head Start classrooms; they comprised 4%, 36% and 37% of teachers in CBO, PreK, and Kindergarten classrooms, respectively.

Classroom Observations

Classroom observations were conducted during two school years. During Year 1 (2018-2019), classrooms were observed during three visits. During Year 2 (2019-2020), only two rounds of observations were conducted because COVID-19 related school closures prevented our spring observations. Over these two school years, 313 children had one observation, 423 had two observations, and 194 had three observations, with an average of 95.27 days between the first and last (second or, if applicable, third) observation (SD = 45.74).

During each classroom visit, trained research assistants videotaped classroom activities. For preschools, all activities that occurred inside the classroom during the day were videotaped. For kindergartens, literacy and mathematics instructional blocks were observed. If the teachers reported not having a specified block of time for literacy or math, the research team asked to observe either the whole morning or afternoon. All observation visits were scheduled at the participating teachers' convenience. Two cameras were used to capture as much of the experiences of individual students as possible, so that observations of multiple children per classroom occurred on the same days and times. If the teacher was with a small group, one camera was located close by that group to capture the instruction and teacher-student talk. Research assistants also took notes to aid later video coding, noting when children entered or left the classroom, or when activities that occurred were not able to be recorded on video.

Coding of the Classroom Observations

Videotapes of the classroom observations from all study sites were sent to the University of California, Irvine site for coding by observers trained on the Optimizing Learning Opportunities for Students (OLOS) coding system (Connor et al., 2020). The OLOS coding interface is a web-based observation tool through which observers record the amount and type of learning opportunities that individual children experience in their classroom (Connor et al., 2020). By touching or clicking the appropriate area of their screen, observers record the amount of time, on a second-by-second basis, that an individual child spends in (a) the specific major content areas of mathematics, literacy, or non-instruction (e.g., transition time between learning activities, classroom disruptions), which were mutually exclusive codes; and two types of instructional contexts comprised of (b) different *instructional grouping strategies,* specifically large group, small group, or individual work; and (c) *management formats*, including teacher-managed, peer-managed, or alone-managed. Each of these codes is further defined in Table 1.

For the present study, instructional codes were limited to mathematics (as specified subsequently) and, for comparison, literacy and non-instruction (as specified in Table 1). The non-instruction code was used only when there were no learning opportunities for students, such as when students were moving from whole class to small-group activities or when teachers reviewed rules or attended to behavioral disruptions. Any instructional activities, including playful interactions, that occurred during the observation were coded by the content. Coders could also record "other instruction" which include activities in social studies, art, music, or science. Those "other instruction" codes were excluded from the present study.

Within the mathematics content area, coders recorded time spent in specific mathematics content areas by touching the appropriate area of the screen. These specific content codes were assigned only when the broad mathematics content area was activated. *Number Knowledge* was coded when activities involved the principles of counting, oral counting, counting sets, properties of numbers, number comparisons; number writing, reading, and recognition; or estimating amounts. *Number Operations* was coded when activities directed children to the idea that numbers can be manipulated or promoted practice on addition and subtraction. In preschool and kindergarten, other tasks coded as *operations* involved visual representations of quantities used for single digit addition; or teaching that numbers are "more than," "less than," "equal to", or the "same as" other numbers. *Algebra* was coded for activities related to identifying, extending, or creating patterns. In OLOS, sorting was also coded as algebra. *Geometry* was coded when children were identifying or describing shapes, angles, space, or attributes of shapes. *Applied Math* was coded for activities such as counting money, using a ruler to measure lengths, using a scale to measure weight, and reading graphs. Engaging with a calendar was scored as Applied Math, although there is debate as to what early mathematics principles are relevant to calendar (e.g., Ethridge & King, 2005). We note that one limitation of the coding system was that it forces a unidimensional content label onto learning activities that may be multidimensional. However, multidimensionality is captured when coding across domains occurs during activities that require shifts from, for instance, applied math to operations. This may occur if an applied problem response is solved with manipulatives or paper and pencil computation. In these ways, the amount of time children participated in mathematics learning activities could be quantified separately across these five content domains.

Duration of Observations

The minimum number of children coded per classroom was 3, with an average of 9.21 (*SD* = 4.41) across grades. Averaged across individuals, observations in preschool classrooms were 127.14 (SD = 32.43) minutes per visit, ranging from 40 to 278 min per visit; kindergarten observations averaged 142.76 (SD = 38.59) minutes and ranged from 49 minutes to 276 minutes. Since the length of observations varied, we prorated (or adjusted) all observed scores for individual children to the same base of 120 minutes. Across-time means for each measure of instructional time and aspects of math instruction were computed because the three observations of instructional time and aspects of math instruction were highly correlated (alpha > .70) except for infrequently observed codes. These across-time averages were used in all analyses.

Training Observers and Ongoing Reliability Assessments

Observers were trained to use OLOS to code the videotaped classrooms by completing an in-person or self-paced online training, led by a gold standard coder (Co-author AS). As part of the training, observers first practiced coding individual students and their teachers using previously coded videotapes until they successfully coded two practice videos with at least 75% exact agreement with the gold standard observer. These videos were from a set of 10-minute video clips created from longer classroom observations used as practice or test videos. If 75% agreement on coding was not reached, trainees completed additional practice videos and then completed a new test. All research assistants who were trained to become reliable observers in this study were able to successfully pass reliability. To ensure that coders remained reliable, all 15 coders completed reliability drift-checks every sixteen weeks after completing the training and successfully becoming reliable. This included coding three children with at least 75% agreement with the gold standard coder.

For the purposes of assessing reliability of OLOS codes, a total of 157 students (115 from preschool and 42 from kindergarten) were double coded by randomly selecting 10% of observations across time points for re-coding. Inter-observer reliability for the specific codes included in the current study was assessed using intraclass correlations between pairs of coders. Reliability was excellent for coding general academic content (.81 for literacy, .94 for mathematics), grouping strategies in mathematics (.93 for large group, .86 for small group, and .91 for individual work); management format in mathematics (> .90), and specific mathematics content (> .85 - .91) except for Applied Math, for which reliability was moderate (.63).

Results

Mathematics in Preschool and Kindergarten Classrooms

The first set of analyses involved comparisons of the relative amount of time children spent in mathematics activities in preschool and kindergarten classrooms, and the nature and content of those mathematics learning opportunities. Time spent in literacy (which included literacy-relevant play) or non-instruction were examined as comparisons to time spent in mathematics activities. Because these three mutually exclusive codes did not apply to activities that fell outside the scope of the codes reported in Table 1, the total time across math, literacy, and non-instruction was below the 120-minute observational period.

The preschool and kindergarten means and standard deviations for each variable appear in Table 2, as do the results of *t*-test comparisons. Effect sizes (*g*) were computed when comparisons were statistically significant to describe the magnitude of the grade-level differences in standard deviation units (Hedges, 1981).

Statistically significant grade differences emerged in (a) total time spent in mathematics, (b) the proportion of time spent in different aspects of mathematics activities, and (c) the instructional contexts of mathematics activities. Specifically, compared to kindergarten classrooms, preschool classrooms spent considerably less time in mathematics activities (g = -2.33) but did not differ significantly in time spent in literacy or non-instruction. During mathematics activities, preschool classrooms spent proportionately more time in large groups (g = 0.67) and proportionately less time in individual work (g = -1.03) compared to kindergarten classrooms. Preschool classrooms also spent proportionately more time than kindergarten classrooms in teacher-managed activities (g = 1.47), and less time working with peers without the teacher (i.e., peer managed activities; g = -0.49) or in alone-managed activities (g = -1.29). The only grade-level differences related to math content were that preschool classrooms received proportionately less instruction in operations (g = -1.94) and slightly more time in applied math (g = 0.50).

Mathematics across Preschool Auspices and Kindergarten

The next set of analyses extended the first set by asking whether the amount and nature of mathematics learning opportunities observed in the three preschool auspices differed from each other and from kindergarten classrooms. Results are summarized in Table 3, showing the means and standard deviations for the four groups of classrooms, the F-test from an analysis of variance, and the pairwise comparisons among means. Effect sizes were computed to describe significant differences, although we acknowledge that these analyses are exploratory given that sample size varies across the three auspice types, with 164 to 370 children across 16 to 43 classrooms per auspice.

Amount of Time Spent in Mathematics Activities

The Head Start classroom spent significantly less time in literacy activities compared to CBO, pre-K, and Kindergarten classrooms (g = - 1.22), and pre-K classrooms spent more time in literacy compared to Kindergarten classrooms (g = .69). Kindergarten classrooms spent more time in mathematics activities than the three preschool groups (g = 2.33), and the three preschool groups did not differ significantly from each other. Head Start classrooms spent more time in non-instruction than did the other types of preschools and kindergarten (g = 0.83).

Instructional Contexts and Content of Mathematics Activities

Comparing grouping strategies, compared to Head Start classrooms, pre-K preschool classrooms spent more of their mathematics time (proportionally) in large group instruction (g = 0.95). Even kindergarten classrooms spent significantly less time in large group compared to pre-K and CBO classrooms (g = - 0.77). Kindergarten classrooms spent a greater proportion of time in individual work compared to all three auspices of preschool classrooms (g = 1.03).

Similar findings emerged for management format: Kindergarten classrooms spent more time in alone-managed activities (g = 1.29) and less time in teacher-managed activities (g = -1. 74) than the three auspices of preschool classrooms. The three types of preschool classrooms did not differ significantly from each other in time spent in different management-formats.

When comparing mathematics content (as a proportion of all time spent in mathematics), the findings were mixed (Table 3). Head Start classrooms spent proportionately more time on numeracy than did CBO preschool or kindergarten classrooms (g = 0.82), and more time on algebra than all three other types of classrooms (g = 1.09). CBO preschool classrooms spent proportionately more time on applied math than did the three other types of classrooms (g = 1.00); and pre-K classrooms spent proportionately more time on applied math than did Head

Start classrooms (g = 0.83). Kindergarten classrooms spent proportionately more time on math operations than the three types of preschool classrooms (g = 1.94).

In summary, significant differences emerged between preschool and kindergarten classrooms in terms of instructional time in mathematics activities and in who managed mathematics instruction; and between Head Start and other preschool or kindergarten classrooms in terms of time in literacy and non-instruction, grouping strategies, and proportional variation in specific math content.

Discussion

Our principal aim was to quantify and characterize mathematics learning opportunities in U.S. preschool and kindergarten classrooms in terms of time children spend in mathematics activities, the mathematics content covered in those activities, and the grouping strategies and management formats children experience during mathematics activities. We also explored whether these aspects of mathematics vary across grades and preschool auspices. Via these aims, our study provides insights into the nature of mathematics activities children experience during the earliest years of schooling and may further identify potential indicators of instructional quality important for early mathematics.

Amount of Time Devoted to Mathematics Activities

Consistent with our hypothesis, when we examined how *much* mathematics occurred in the 77 preschool and 24 kindergarten classrooms participating in our study, the answer can be summarized as, “very little,” with preschool classrooms averaging just under 6 minutes of mathematics activities and kindergarten classrooms averaging 30.6 minutes, during a 120-minute observation. Preschool program auspice did not account for the significant difference in overall time spent in mathematics between grades, because mean time spent in mathematics was very low across all three auspices (3 to 7 minutes on average). Considered another way, mathematics comprised approximately 5% of our observational period in preschool classrooms regardless of program auspice, and 25% of our observations of kindergarten classrooms, on average.

The preschool findings are consistent with prior observations that mathematics-focused activities occur during only a small fraction of observation periods in U.S. preschool classrooms (~6%-9%; Howes et al., 2008; Coelho et al., 2020) and European preschools (Coelho et al., 2020). When higher rates were observed in one other U.S.-based study by Phillips and colleagues, (i.e., 17% as reported by Phillips et al., 2009), the higher rate may have related to the researchers' intentional focus on a unique context: observing preschool classrooms in Tulsa, Oklahoma, where the program performance standards required all classrooms to meet high standards regarding classroom, program, and teacher characteristics and qualifications. This context may have contributed to the higher rate of mathematics-focused instruction in preschool classrooms on average (Phillips et al., 2009), but this "higher" rate was nevertheless low relative to time spent in mathematics in the kindergarten classrooms, at least in our study (25%). It is worth noting that Phillips and colleagues' comparison sample of preschools in 12 other U.S. states yielded a rate of 9%, similar to rates reported in other studies and our findings.

Also consistent with our hypotheses and prior research, grade-level averages for total time spent on mathematics fell short of the literacy-related focus we observed in these same classrooms, during the same observational periods. We were not surprised to observe more literacy than mathematics in both grades, but the degree to which this occurred was striking: Literacy-focused activities comprised about 50 of the 120 minutes of observation time – about 42% of the time observed – on average, in both grades; this means time devoted to literacy was 1.7 times greater than the amount of time devoted to mathematics in kindergarten classrooms, and 9 times greater than the time devoted to mathematics activities in preschool classrooms. The latter exceeds the roughly two-fold ratio reported in other studies of literacy and math in U.S. classrooms (e.g., Coelho et al., 2020; Howes et al., 2008~~)~~ and other nations (Coelho et al., 2020).

It was important to assess if these large differences between mathematics and literacy were partially related to OLOS coding of play in preschool and kindergarten, as specified in Table 1: free play, center-based play, dramatic play, and imaginative play are considered subtypes of Literacy based on evidence that children may demonstrate their most advanced language skills during play, and that these language skills are strongly correlated with emergent literacy (reviewed by Roskos & Christie, 2001). We note that early mathematics activities can also be playful games or center activities but in OLOS, engagement in free choice or center activities that focused on math domains were coded as mathematics. When we informally examined whether subtracting time in "play" from time spent in literacy affected the ratio between literacy and mathematics activities, we found that although the ratio changed considerably, literacy nevertheless still dominated time observed. In Kindergarten classrooms, the difference is negligible, because children spent less than one minute in play during the observation period, on average. Among preschool classrooms, 34.47 of the 53.79 minutes children spent in literacy was, on average, coded as play, so the remaining 19.32 minutes of time spent in literacy activities is 3.25 greater than time spent in mathematics activities. Similar comparisons emerged across preschool auspices, demonstrating that the disproportionate amount of time devoted to literacy over mathematics was not an artifact of OLOS coding play as literacy.

This imbalance between time spent in literacy and mathematics is revealing because it makes clear that the reduced focus on mathematics cannot result from an overall lack of *academic* focus given how much time classrooms in our and other studies spent on literacy, including literacy activities that were not play. Likewise, the limited focus on mathematics cannot stem from insufficient *time* to address both literacy and math, because in both grades we observed non-instruction for about 30 minutes on average (25% of the observation period), and remaining proportions of classroom activities such as social studies, music, art, and science accounted for additional time during the observation period. Thus, measuring time spent in literacy allowed us to rule out limited time or a disregard for academics as potential explanations for the paucity of mathematics in early childhood classrooms.

Although we did not address the reasons for the large discrepancy in time devoted to literacy versus mathematics, we draw from a large body of research to speculate that this discrepancy may partially reflect that preschool and kindergarten teachers are either less aware of the importance and depth of early mathematics (e.g., Lee & Ginsburg, 2009), less knowledgeable of how to engage children in early mathematics (e.g., Li, 2021; Jenßen et al., 2022), have less access to professional support to pursue mathematics teaching goals, or some combination of these explanations, all relative to their own preparedness to teach early literacy. Moreover, preschool teachers' beliefs about early mathematics and literacy instruction vary with auspice (Lee & Ginsburg, 2007). These potential explanations may reflect the current state of existing early mathematics pre- and post-service professional development opportunities, curricula, and teaching supports, or even buy-in from local educational agencies. Regardless of what mechanisms account for our findings, we conclude that in our study, there was very little mathematics in preschool and kindergarten classrooms, especially compared with literacy.

Our exploratory analyses comparing preschool auspices and kindergarten revealed only one notable difference across the three preschool auspices with respect to time spent in mathematics, literacy, or non-instruction: On average, Head Start preschool classrooms spent significantly *less* time engaged in literacy activities compared to the three remaining auspices (i.e., 35 versus about 50 minutes on average in the other preschool classrooms and 50 minutes on average in kindergarten). We are cautious interpreting this finding given the exploratory nature of our secondary analyses and the fact that the differences are based on only 17 Head Start classrooms (163 children). In speculating potential explanations for the differences, we consider Head Start's greater emphasis on the whole child rather than prioritizing an academic focus. Consistent with this notion, Phillips and colleagues (2009) also observed less literacy in their Oklahoma Head Start versus Oklahoma public pre-K classrooms; however, that difference was not statistically significant; nor was there a difference across auspices among their comparison classrooms. Unfortunately, in our study, less time in literacy did not afford more time for mathematics; instead, Head Start classrooms spent more time in non-instruction compared to the other preschool and kindergarten classrooms. Our analyses of preschool auspices did not, therefore, alter our conclusion regarding the paucity of mathematics in preschool classrooms.

Mathematics Content

Our findings related to specific mathematics content are based on the proportion of time devoted to each content area relative to total time spent in mathematics overall, so the findings must be interpreted in the context of how little mathematics occurred in classrooms. During the brief intervals when mathematics activities did occur, on average, about half the time focused on numeracy, in both grades. This finding is consistent with disproportional focus on numeracy in most early math curricula and materials (Claessens et al., 2021), and with preschool teachers' mathematics content knowledge in the U.S. (Lee & Ginsburg, 2007) and other nations (e.g., Lee, 2017). In our study, 27% of math content in the kindergarten classrooms focused on operations in contrast to 1% of math content in preschool classrooms. In both grades, less than 14% of mathematics content focused on geometry, and less than 6% focused on patterning or other aspects of algebra. The two latter findings are consistent with Claessens and colleagues' (2021) review of preschool curricula. Again, all these proportions of time are based on an average denominator of about 6 or 30 minutes, for preschool and kindergarten classrooms, respectively.

These general trends in mathematics content held across preschool auspice, with a few exceptions, as summarized in Table 3: Head Start classrooms were disproportionately more focused on number knowledge compared to CBO preschool classrooms or kindergarten classrooms; and spent a larger proportion (15%) of their very limited mathematics time in algebra-related activities (e.g., identifying patterns) compared to all other classrooms. Although the difference in the proportion of time spent in algebra-related activities is statistically significant, our findings are exploratory and they may be less meaningful in practice because both groups of preschoolers spent less than a minute engaged in these algebra activities on average, per 120-minute observation. Interestingly, when Claessens and colleagues (2021) coded two curricula used by most Head Start programs in the U.S., the activities coded as operations and algebra comprised about 15% of the activities per curriculum.

Findings for applied mathematics were highly variable, comprising from 6% - 43% of all mathematics activities across the three preschool auspices. Perhaps this wide variation is an artifact of how much more broadly this code was defined. For instance, calendar time was coded as Applied Math even if the time was not focused on numbers or measurement; as were reference to time, money, charts, or word problems. By contrast, there was less variation in behaviors coded as number knowledge or geometry, and less variation in the proportion of mathematics time spent on number knowledge or geometry. Number knowledge accounted for the largest proportion of all mathematics content for all classroom auspices and grades (44 to 70%), and geometry accounted for about 6%-13% of all mathematics activities across all classrooms. Considered together, our findings highlight that mathematics content in preschool and kindergarten is limited overall and in terms of breadth of mathematics content, especially in preschool classrooms.

Classroom Grouping Strategies and Management Formats

There are different ways to interpret the significant differences in *amount* of time spent on mathematics between preschool and kindergarten classrooms. Six minutes in preschool classrooms may be viewed positively if it reflects avoiding inappropriate academic emphases on preschool becoming the new kindergarten, much like concerns that kindergarten is the new first grade (Bassok et al., 2016). An alternative view is that 6 out of 120 minutes represents a missed opportunity for developmentally appropriate foundational mathematics activities that may diminish current and later academic inequities in mathematics achievement. Indeed, prior research suggests that early mathematics experiences are related to kindergarten readiness and early mathematics gains, particularly for children at higher risk for underperformance in mathematics (e.g., Sonnenschein & Galindo, 2015). Both views must be evaluated in the context of *how mathematics time was used*. For instance, in their questionnaire-based study of teaching practices, Bassok and colleagues (2016) found that kindergarten teachers who reported spending more time teaching reading and mathematics in 2010 (compared to 1998) also reported that their instruction was largely teacher-led (Bassok et al., 2016); others report that whole group (Wang et al., 2016) and teacher-led instruction may not be as effective for young children compared to peer- or individually-guided play in general (e.g., Weisberg et al., 2013) and for mathematics (Fisher et al., 2013). Teacher-led whole group instruction may diminish opportunities for active learning through exploration, so researchers have suggested that an emphasis on large-group teacher-led instruction may be associated with negative outcomes in elementary school even following potential short-term gains for kindergarten readiness (Durkin et al., 2022). These relations, however, might not be linear, and child-initiated may not always be superior to teacher-led, as demonstrated by Vaisarova and Reynolds (2022). They found that learning gains linked to increases in child-initiated activities differed for three- and four-year olds and followed a U-shaped relation for younger vs older preschoolers.

One concern with large-group teacher-led instruction in early childhood is its developmentally inappropriate delivery or goals, particularly if messaging to increase mathematics learning opportunities in early grades signal a move to shift activities designed for kindergarten or first grade to preschool and kindergarten, respectively. In the present study we did not measure developmentally appropriate activity per se, but it was revealing that preschoolers were coded as engaging in much more play – 34 minutes on average during the 120-minute observation period – compared to kindergartners who spent less than one minute in play during the observation, on average. The latter is consistent with concerns of kindergarten as the “new first grade.” Regarding the former, 34 minutes of play may be viewed as appropriate for preschoolers, but that notion could be debated in the context of it representing a fraction of the 2-hour observation block.

With regard to mathematics activities specifically, time spent in large group raises additional concerns regarding developmentally appropriate practices. Clearly, *some* large-group instruction – particularly intentional goal-oriented instruction – may be effective and developmentally appropriate for preschoolers, such as when it is designed to prepare children for subsequent child-directed small group activities (e.g., Sarama & Clements, 2004). Yet there is evidence that teachers of 4- and 5-year-olds in the U.S. are less intentional in their mathematics instruction compared to preschool teachers of 5-year-olds in China, based on teacher-reports of the number and types of goals underlying the mathematics activities in their classrooms and on whether teachers report such goals at all (Li et al., 2015). Moreover, recommendations for developing evidence-based developmentally appropriate preschool learning environments strongly advocate for less rather than more time in teacher-led large group formal instruction in preschool classrooms (Burchinal et al., 2023). Although we cannot infer the quality of the large-group teacher-led activities observed in this study and accept that some time spent in large-group activities may well have been pedagogically beneficial, what is unfortunate is that more than two thirds of preschoolers' mathematics activities (68%) were large-group oriented, and nearly all (91%) were teacher-led. Future studies are needed to delineate features that differentiate effective versus ineffective large-group teacher-led mathematics engagement in early childhood classrooms, and that focus on both quantity and quality of children's mathematical learning opportunities.

Across-grade comparisons of grouping strategies were mixed: In both grades, large group activities exceeded individual or small group activities, but the extent to which this was observed varied with grade. Large group activities comprised a significantly larger percentage of mathematics activities in preschool classrooms compared to kindergarten, a finding driven by high averages observed in public pre-K and CBO preschool classrooms: in those programs, large group comprised 67% or more of all mathematics activities. By contrast, individual activities as a grouping strategy occurred less frequently overall in preschool (5 to 12% of all mathematics time), whereas the amount of time children independently engaged in mathematics activities comprised about 32% of time spent in math in kindergarten. These differences are important to examine in future research because of the benefits afforded by small-group instruction, as shown for both literacy (Connor et al., 2007) and mathematics (Connor et al., 2018). Another benefit of small group instruction is that it can support guided play as instruction, where intentional learning goals are embedded in structured play opportunities that allow for more exploration than either teacher-led large group tasks or completely child-led free play (Weisberg et al., 2013). Such formats have been demonstrated to promote learning of mathematics concepts, such as geometry, in experimental studies contrasting these formats (e.g., Fisher et al., 2013). Regarding individual work, although these activities were not necessarily individualized to specific children, small group and individual work may support the kind of intentional individualization that is associated with learning gains (e.g., Wang et al., 2016). In summary, we observed very little mathematics instruction in preschool and kindergarten classrooms, and when it was observed, it was predominantly teacher-led, large-group based, and focused on number knowledge, with some variation across classrooms and preschool auspices.

Study Strengths and Limitations

Despite its primarily descriptive nature, strengths of our study include the large number of classrooms we observed, our focus on children's experiences rather than teacher-reported data, and the economic and geographic diversity across participating classrooms drawn from all four major regions of the U.S. Another strength is our long observation period, three to five hours per classroom and per child participant, on average. The study highlights the importance of understanding mathematics experiences in preschool classrooms: Although our findings were limited by the paucity of such experiences, it is essential that early childhood researchers and policy makers are aware of the current state of such limited mathematics learning opportunities in preschool classrooms.

Key limitations of the study are related to the study sample. Since our classrooms were all in the U.S., our findings do not generalize internationally. The sample was a convenience sample and thus is not representative of preschool and kindergarten settings across the U.S. Only some of our participating sites included preschool classrooms of all three auspices, leading to confounding between preschool auspice and site which in turn decreases our confidence in the differences we observed between auspices. We thus cannot infer that descriptive features of one auspice in our study generalize to that auspice overall and must interpret our exploratory analyses with caution. Still, our findings contribute to the notion that auspice differences are worthy of further study, especially considering evidence that preschool teachers' beliefs about mathematics education also vary between auspices (Lee & Ginsburg, 2007). The variations we observed across auspices in mathematics time, mathematics content, and teachers' grouping strategies or management formats may be more marked in a larger and more representative sample of preschools across the U.S.

Like all observational studies, our findings are limited by our instrument, so we cannot draw comparisons between studies that employed different observation tools, such as the CLASS (e.g., used by Phillips et al., 2009). Also, we did not focus on other factors known to be associated with teaching quality, center or school quality, or student outcomes (e.g., Burchinal, 2018; Schimdt et al., 2023) that have been linked to child behavior and academic outcomes, including mathematics (Burchinal et al., 2010).

Summary and Conclusions

In this study, we found that mathematics activities comprise relatively brief proportions of classroom time overall, and when mathematics occurs, the instructional focus is likely teacher-led number knowledge activities that –in preschool—are delivered in large groups. The decision to pursue this descriptive study is by no means an indication that time spent in mathematics is the most important factor underlying early mathematics learning opportunities – but the findings do offer an important insight, because even when mathematics activities are of high quality, *their value may nevertheless be diminished if they account for a negligible portion of a child's typical preschool or kindergarten experience*.

Still, determining what amount of time spent in mathematics activities is appropriate or optimal requires the consideration of child, teacher, and program characteristics, including but not limited to grouping strategies and management formats. Our study makes clear that these features vary across early learning settings; but future research is needed to identify to what extent this variability is consequential to learning. For instance, preschool and kindergarten children's mathematics learning is related to teachers' use of probes, scaffolding, and follow-up questions that support the development of mathematical thinking (Webb et al., 2009) and even the quality of teachers' mathematics discourse, such as whether explanations convey basic or more complex material (e.g., Webb et al., 2008). These teacher factors, program factors (e.g., Temple et al., 2022), and pre-existing differences (Bailey et al., 2016) may contribute to whether learning gains emerge and whether they are maintained or fade out over time.

In their international study of literacy in preschool education, Cebolla-Boado and colleagues (2017) described preschool education as "the great equalizer" for literacy skills, but to our knowledge no comparable international study has been conducted for early mathematics. Based on our findings, it is difficult to imagine that preschool mathematics is the great equalizer for early mathematics, in the U.S. or internationally, given how little preschool mathematics we observed and that others have reported. In some cases, researchers have found that the mere presence of mathematics in preschool may lead to short-term gains but long-term losses (Durkin et al., 2022), small gains that become null over time (Watts et al., 2017), or gains that are sustained over time (Bailey et al., 2016), likely depending on the quality of that instruction and other factors. Although early mathematics skills and knowledge at Preschool, Kindergarten or Grade 1 predict mathematics achievement through middle and high school, these longitudinal associations measure skills and knowledge about, not mere exposure to, mathematics.

In their examination of fadeout of early mathematics intervention gains, Bailey and colleagues (2016) found that fadeout was largely attributed to individual differences that were present at school onset and persisted over time. These researchers further argued that fadeout may be partially attributed to instruction that – due to initial student differences – does not establish a solid foundation of understanding before advancing to higher levels, or that otherwise remains focused on basic levels for the long term. Thus, some mathematics instruction may be beneficial for supporting skills known to be foundational for later mathematics, but its presence alone is insufficient to ensure mastery unless it is also pedagogically and developmentally appropriate (Cross et al., 2009). Our findings show that a prerequisite factor – the presence of mathematics instruction in preschool – is extremely limited in preschool classrooms and, when present, is primarily delivered through grouping strategies and management formats that are not associated with higher quality developmentally appropriate instruction.

Accordingly, our findings have some implications related to efforts to align mathematics instruction in early childhood. When school districts attempt to align math instruction across grades, their alignment efforts rarely include preschool classrooms, even when the school district administers its own pre-K program for 4-year-olds (Stein & Coburn, 2023). This lack of intentional alignment may contribute to the substantial instructional redundancy in pre-K and kindergarten mathematics described previously (Engels et al., 2013) and observed in our study, and it may also indirectly discourage incorporating meaningful, intentional, developmentally appropriate mathematics in preschool. This lack of attention then diminishes the likelihood of consistency underlying instructional alignment from its very onset, at preschool. However, instructional alignment assumes the existence of some instruction in preschool, which was barely evident in the present study. More mathematics should be a goal, but it must be aligned with what we know about how young children learn mathematics. In our study, some aspects of early mathematics differed with program auspice, suggesting that recommendations to increase and improve early mathematics may need to also consider auspice characteristics.

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Table 1

Overview of Categories in the Optimizing Learning Opportunities for Students (OLOS) Coding System

Instructional dimension	Definition	Additional information
Academic content of instruction [a]	Specifies the content area of instruction.	Hierarchically nested within each content area are codes that specify subject area content in more detail.
Literacy [b]	Any activity focused on language or literacy.	The content within Literacy is further specified as Code-focused (e.g., phonics instruction), Meaning-focused (e.g., story time, writing, read aloud), or Play (e.g., individual or cooperative free play or center time that was not obviously letter- or number-related). Play is included within Literacy in preschool or kindergarten only, due to its role in developing language skills. [b]
Mathematics	Any activity focused on mathematics content.	Instructional content within Mathematics is further specified as Number knowledge, Operations, Algebra, Geometry, and Applied mathematics.
Non-instruction	Activities where there is not an opportunity to learn. Some non-instructional activities may support learning.	Examples of activities coded as Non-instruction include transitions between activities, students getting materials, pauses in instruction for classroom management.

Instructional dimension	Definition	Additional information
Context	Refers to the size of the group in which instruction occurs and who is managing instruction.	
Grouping strategy [a]		
Large group [c]	Student is in an activity that involves nine or more children.	Examples include student participating in a lesson taught by the teacher to the whole class, participating in a group discussion involving the whole class, or participating in a class read aloud.
Small group	Two to eight children, including the target child, are involved in an activity.	For this Grouping strategy code, Focus of attention can be coded as Teacher-managed (if 2-8 children are working with the teacher) or peer-managed (if 2-8 children are working together without the teacher). If child is sitting in a small group but working alone, then context code is Individual.
Individual	Student is completing an activity alone.	Either the student is learning in a one-to-one setting with their teacher or working on an independent activity alone. Individual can also be coded if two or more children are in a group but the children are engaged in parallel play.

Instructional dimension	Definition	Additional information
Management format [a]	Refers to who has responsibility for focusing the child's attention during the learning activity.	
Teacher-managed	The teacher is directing the attention of the student or group of students during the activity.	Includes activities such as reading aloud with the teacher, small group math instruction led by teacher, small group stations led by the teacher, and class discussion led by the teacher about a story read in class.
Peer-managed	Children are in a group directing their own or each others' attention. Can only be coded with a Small group grouping strategy code.	Examples include partner reading, group play with blocks.
Alone-managed	Child is working individually and directs own attention and pace of activity.	Examples include silent sustained reading; math worksheets completed on the students' own. Alone requires a Grouping strategy code of Individual, but the reverse is not true. For instance, a student receiving one-on-one instruction from the teacher would receive a Grouping strategy code of Individual, but a Management format code of Teacher-managed.

Note. This table includes only OLOS categories most relevant to the present paper. For a comprehensive description of OLOS see Connor et al., 2020).

[a] *Codes under each subheading are mutually exclusive.*

[b] Because play is excluded from literacy for Grades 1 and higher, play is sometimes excluded from literacy codes for Grade K in studies using OLOS that focus on literacy in grades higher than Kindergarten. In view of our focus on preschool and kindergarten experiences we included literacy-relevant play in our analyses but also briefly compare literacy with or without play in the Discussion section.

[c] Large group is sometimes referred to as Whole class (e.g., Connor et al., 2020); we chose to label this code Large group because these occurrences include but are not exclusively whole class activities.

Table 2

Comparisons of Mathematics Activities in Preschool and Kindergarten Classrooms

Instructional dimension	Grade						Comparison	
	Preschool			Kindergarten				
	N [a]	*M*	*SD*	*N*	*M*	*SD*	*t(99)* [b]	*g*
Academic content (minutes out of prorated 120-minute observation)								
Literacy	77	53.81	18.88	24	50.95	17.69	.66	
Mathematics	77	5.93	7.30	24	30.61	17.28	9.83***	-2.33
Non-instruction	77	30.18	10.60	24	29.65	9.50	0.22	
Grouping strategy (proportion of mathematics instruction)								
Large group	76	0.68	0.35	24	0.45	0.31	2.96**	0.67
Small group	76	0.22	0.31	24	0.24	0.28	0.23	
Individual	76	0.10	0.19	24	0.32	0.27	4.37***	-1.03
Management format (proportion of mathematics instruction)								
Teacher-managed	76	0.91	0.17	24	0.63	0.24	6.49***	1.47
Peer-managed	76	0.03	0.11	24	0.09	0.15	2.28*	-0.49
Alone-managed	76	0.06	0.13	24	0.28	0.26	5.57***	-1.29
Mathematics content (proportion of mathematics instruction)								
Number knowledge	76	0.55	0.32	24	0.44	0.33	1.39	
Operations	76	0.01	0.05	24	0.27	0.26	8.26***	-1.94
Algebra	76	0.05	0.15	24	0.01	0.02	1.52	
Geometry	76	0.08	0.16	24	0.13	0.22	1.21	
Applied	76	0.31	0.32	24	0.16	0.21	2.21*	0.50

Note. [a] Mathematics activities were not observed in one preschool classroom so proportion of time in specific math activities could not be computed for that classroom. [b] *df*=99 for first three rows and 98 for remaining rows. Codes within an instructional dimension are mutually exclusive.

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

Table 3

Comparisons of Mathematics Instruction in Classrooms by Preschool Auspice and Kindergarten

Instructional dimension	Preschool auspice						Kindergarten		$F(3,97)$ [a]	Significant contrasts; effect size (g) [b]
	Head Start (n = 18 [c])		Community-based organization (n = 43)		Public prekindergarten (n = 16)		Public Kindergarten (n = 24)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Academic content (prorated to 120m)										
Literacy	35.39	9.14	57.43	15.10	64.79	22.34	50.95	17.69	11.02***	(PK, CBO, K) > HS; HS -1.28 PK > K; K -.69
Mathematics	3.65	3.11	7.71	9.00	3.72	3.38	30.06	17.28	33.42***	K > (HS, CBO, PK); K 2.33
Non-instruction	36.79	5.92	29.29	9.68	25.13	13.60	29.65	9.50	4.25**	HS > (CBO, PK, K); HS .83
Grouping strategy (proportion of mathematics instruction)										
Large group	0.56	0.29	0.67	0.38	0.83	0.26	0.45	0.31	4.80**	(PK, CBO) > K; K -.77 PK > HS; HS -.95
Small group	0.34	0.30	0.21	0.34	0.12	0.16	0.24	0.28	1.53	NSD
Individual	0.10	0.17	0.12	0.22	0.05	0.13	0.32	0.27	6.70***	K > (HS, CBO, PK); K 1.03

Instructional dimension	Preschool auspice						Kindergarten		$F(3,97)$ [a]	Significant contrasts; effect size (g) [b]
	Head Start (n = 18 [c])		Community-based organization (n = 43)		Public prekindergarten (n = 16)		Public Kindergarten (n = 24)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Management format (proportion of mathematics instruction)										
Teacher-managed	0.91	0.17	0.89	0.19	0.97	0.05	0.63	0.24	14.81***	(HS, CBO, PK) > K; K -1.47
Peer-managed	0.01	0.04	0.04	0.15	0.01	0.01	0.09	0.15	2.12	NSD
Alone-managed	0.08	0.17	0.07	0.14	0.02	0.05	0.28	0.26	10.65 ***	K > (HS, CBO, PK); K 1.29
Mathematics content (proportion of mathematics instruction)										
Number knowledge	0.70	0.27	0.46	0.31	0.62	0.35	0.44	0.33	3.34*	HS > (CBO, K); HS .82
Operations	0.02	0.04	0.02	0.06	0.00	0.01	0.27	0.26	22.39***	K > (HS, CBO, PK); K 1.94
Algebra	0.15	0.23	0.03	0.11	0.01	0.05	0.01	0.02	5.83**	HS > (CBO, PK, K); HS 1.09

Instructional dimension	Preschool auspice						Kindergarten		F(3,97) [a]	Significant contrasts; effect size (g) [b]
	Head Start (n = 18 [c])		Community-based organization (n = 43)		Public prekindergarten (n = 16)		Public Kindergarten (n = 24)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Geometry	0.07	0.15	0.06	0.16	0.11	0.15	0.13	0.22	0.80	NSD
Applied	0.06	0.13	0.43	0.33	0.25	0.29	0.16	0.21	9.95***	CBO > (HS, PK, K); CBO 1.00 PK > HS; PK .83

Note. HS =Head Start; CBO = Community-based organization; PK = Prekindergarten; K = Kindergarten. All codes within each instructional dimension are mutually exclusive.

[a] df_e = 97 for first three rows and 96 for remaining rows. Mathematics activities were not observed in one Head Start classroom so proportion of time in specific math activities could not be computed for that classroom.

[b] Effect size (ES) values in the text may vary in valence from values in this table depending on whether we described the reference group as having a positive or negative difference relative to comparison group(s). Specific ES values reflect the indicated individual auspice contrasted to either one or the multiple auspices appearing in the immediately preceding reported contrast.

[c] Sample size for Head Start classrooms is 18 for first three rows, 17 for remaining rows due to lack of observed math activities in one classroom.

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