Effects of Pre-K and Kindergarten Classroom Quality on Student Achievements

Introduction

There is an ample of evidence in the literature that prekindergarten (pre-K) programs significantly affect students' academic outcomes in later years (DeAngelis et al., 2020). However, positive effects from pre-K may disappear by the end of kindergarten (K) (Lipsey et al., 2018), a known phenomenon called as the fadeout effect in early childhood research literature. On the other hand, higher-quality preschool programs are reported to have more significant effects (Yoshikawa et al., 2016). For example, economically disadvantaged students who attended high-quality public pre-K performed better than those who did not attend public pre-K or those who attended lower-quality public pre-K at third-grade state-level reading assessment (Sanborn et al., 2016). Based on this varying evidence regarding the effects of pre-K education and its interaction with the level of classroom quality, the interest in the effects of high-quality early childhood education on later years' student outcomes persists. Notably, the question of whether high-quality pre-K education would have a more prominent and persistent impact on pupils' later-year academic outcomes warrants further investigation.

Literature Review

A large body of literature has been built on the classroom quality of pre-K and its short- and long-term effects throughout the upcoming school years. Mashburn et al. (2008) investigated the association between pre-K classroom quality and students' academic, language, and social skills in 10 states by controlling several demographic variables including race, mother's education, and socioeconomic status. They found no significant association between academic achievement and

overall pre-K quality. Ansari and Pianta (2018) examined the long-term benefits of childcare and classroom quality in elementary schools. They found small but statistically significant associations between high-quality childcare and academic performance. They also pointed out that it is vital to understand whether such a reported pattern remains among low-income children and families. A randomized trial of a Tennessee Voluntary pre-K (VPK) program found that the positive VPK effects on achievement primarily disappeared by the end of K, even though children who participated in VPK experienced considerably more significant gains in literacy, language, and mathematics skills during the pre-K year than the children in the control group (Lipsey et al., 2018). However, the researchers found no relation between classroom quality and children's achievement. Durkin et al. (2022) examined the effects of the statewide pre-K programs through the end of sixth grade but found no long-term effects on academic outcomes.

In addition to inconclusive evidence in the literature on the effects of high-quality pre-K education, another crucial question to be answered is whether the effects of quality vary based on students' characteristics, mainly their socioeconomic status. Researchers endeavored to find potential compensating effects of high-quality childcare for underrepresented students, especially with low socioeconomic levels. For example, Burchinal et al. (2010) found that high-quality classrooms may be necessary for better social and academic skills in pre-K programs for lowincome children. In a longitudinal study focused on pre-K 3 and 4, Ansari and Winsler (2013) found that the low-income, at-risk preschoolers made notable school readiness gains relative to national norms throughout the two years. This and the former study points to the fact that early childhood education programs may benefit low-income children's school readiness. Bassok et al. (2019) also found that positive associations between preschool and academic outcomes are more extensive for children in private rather than public preschools, yet they did not use the quality as a

factor. However, they highlighted the rigor of considering quality factors as these data may enhance our understanding of the conditions under which preschool benefits persist.

Purpose of the Study

This study is interested in exploring the effects of pre-K and K classroom quality on students' K achievements, and further to investigate the varying effects of quality based on students' demographic characteristics. Another aim of the current study is exploring the interactive effects of pre-K and K classroom quality measures with each other and students' status of limited English proficiency (LEP) and socioeconomic status. The latter is hoped to shed more light on whether later year's quality can compensate for lack of pre-K education and also if either pre-K or K quality show significant effects of students at risk due to being LEP or low income.

Methods

Data and Sample

The study sample was comprised of N=1,969 students from a school district of a metro city located in a southwestern state of the US. The data had two levels, where students are nested within classrooms (and a single teacher) at K. All data observations were structured at the student level and contained students' demographic information, K academic scores, and classroom-level quality measured at pre-K and K with the Classroom Assessment Scoring System (CLASS) observation tool (Pianta et al., 2012). A list of the data variables used in the analyses can be found in Table 1.

Student outcomes were the K reading and mathematics percentile scores from the state's assessment test. Prior to analyses, percentile scores were normalized to have a standard normal

distribution. CLASS tool measures quality in three domains: Emotional Support, Classroom Organization, and Instructional Support. The overall (i.e., composite) quality for a classroom is computed as the average of the mentioned three domain-scores. K-level classroom quality scores were the continuous composite quality measures. Pre-K quality, however, was handled by dichotomizing the overall quality (low/high) following the score thresholds suggested by Pianta et. al (2012) per domain. We adopted this strategy to be able to include the K students who did not go to pre-K in our analyses. As a result, a new three-category variable named as pre-K education status was derived as NO pre-K, low-quality (LQ) pre-K (if any of the domain score is below the quality thresholds), and high-quality (HQ) pre-K (all domain scores were higher than the quality thresholds). Student demographics such as ethnicity were all categorical variables and dummy-coded versions were used in the analyses. Table 2 shows the descriptive statistics of variables.

Analysis

We conducted two-level (students nested within K classrooms) hierarchical linear model analyses for reading and mathematics outcomes. Based on the conceptual framework from multilevel modeling (Robson & Pevalin, 2016), the two-level models aim to examine the relationships between K academic performance and pre-K education status, as well as K classroom quality scores, while controlling for students' background variables.

In the first level of the two-level model (Equation [1]), K-grade assessment scores (Y) in two subjects (s, reading or mathematics) for a child (i) who is in a classroom (j) is modeled as a function of the overall mean score, the characteristics of children and/or family, and the dummycodes for the pre-K education status, where LQ pre-K was the reference category. Note that r_{ij} in

Equation 1 is the level-1 residual term and the classroom *j* refers to K classroom of a student *i*. Also, pre-K classroom-quality is modeled at the student-level as part of the pre-K education status.

$$Y_{ij}{}^{s} = \beta_{00} + \beta_{01}[Hisp] + \beta_{02}[White] + \beta_{03}[Other] + \beta_{04}[MALE] + \beta_{05}[LEP] + \beta_{06}[ECON\_DIS]$$

$$+\beta_{07}[NoPK] + \beta_{08}[HQPK] + r_{ij} \qquad [1]$$

Equation [2] specifies the second-level model in which the adjusted mean K score for children in each classroom is a function of the grand mean and the level-two error term.

$$\beta_{00} = \gamma_{00} + u_{0j} \qquad [2]$$

Then, we added a level-two predictor to Equation 2, composite K quality score (k_{com}) such that

$$\beta_{00} = \gamma_{00} + \gamma_{01}[k_{com}] + u_{0j}. \qquad [3]$$

Finally, we fitted a model with k_{com} as the level-2 predictor and the interactions of k_{com} as well as the pre-K education status with indicator of being economically disadvantaged (ECON_DIS) and limited English proficiency (LEP) (see Equation 4).

$$Y_{ij}{}^{s} = \beta_{00} + \beta_{01}[Hisp] + \beta_{02}[White] + \beta_{03}[Other] + \beta_{04}[MALE] + \beta_{05}[LEP] + \beta_{06}[ECON\_DIS]$$

$$+\beta_{07}[NoPK] + \beta_{08}[HQPK] + \beta_{09}[NoPK] * [k_{com}] + \beta_{10}[HQPK] * [k_{com}]$$

$$+\beta_{11}[NoPK] * [ECON_{DIS}] + \beta_{12}[HQPK] * [ECON_{DIS}] + \beta_{13}[k_{com}] * [ECON_{DIS}]$$

$$+\beta_{14}[LEP] * [NoPK] + \beta_{15}[LEP] * [HQPK] + \beta_{16}[LEP] * [k_{com}] + r_{ij} \qquad [4]$$

We used lme4 package (Bates et al., 2015) and stargazer (Hlavac, 2022) of R (R Core

Team, 2018) for the analyses.

Results

We fitted five models per outcome (reading and mathematics). The baseline models included only the random intercept. Following models extended the baseline model by adding relevant predictors and interaction terms. The full list of the fitted models is summarized in Table 3 along with model-data fit information and intraclass correlation coefficient (ICC). Highest model fit levels and existence of significant interaction effects led to selection of the final models (Model 5) for reading and mathematics outcomes.

Parameter estimates for the final model per outcome are presented in Table 4. For reading scores, the coefficients of Hispanic, MALE, and LEP indicators and the main effect of K classrooms quality scores were statistically significant ($p<.05$). Model estimates related to main effects of background variables showed that Hispanic students overperformed their Black peers (reference group) in both mathematics and reading, controlling for all other covariates. Genderbased differences only observed for reading scores with higher average scores for female students than males. The effect of LEP was negative for mathematics but positive for reading scores.

Looking at the significant interaction effects, it can be interpreted that overall K quality score is positively associated with reading scores for those who did not go to pre-K ($p<.05$). Further, the negative interaction between No PK and ECON_DIS clearly showed that both reading and mathematics scores are expected to be lower for those who did not go to pre-K and also identified as having a low economic status. The negative and significant interaction between

HQ_PK and ECON_DIS for mathematics scores indicated that having a high-quality pre-K education still cannot compensate for the prominent negative effect of low economic status. Lastly, the positive and significant interaction effect between LEP and k_com for both outcomes indicated that higher quality K classrooms are positively associated with higher scores for those who are identified as LEP. In other words, an LEP student in a classroom with higher K classroom quality is expected to have higher mathematics and reading scores compared to an LEP student in a K classroom with lower overall quality, while holding all other variables constant.

Discussion

This study aimed to examine the association between students' pre-K education status (including pre-K quality if they attended), K classroom quality, and academic performance in reading and mathematics at K. First, it was confirmed that the most challenging condition, namely, not having a pre-K education and being economically disadvantaged resulted with negative effects on both type of K outcomes. This finding supports Ansari and Winsler (2013), who pointed out that having a pre-K education can benefit low-income children. The effect of high-quality pre-K, however, did not seem to help to mitigate the negative effects of low economics status in our results. This is in line with findings of Yoshikawa et al. (2016) and Sanborn et al. (2016). Also, we did not observe any significant difference between being in low- vs high-quality pre-K in terms of K academic achievements.

Even though we could not see a strong association between pre-K quality and K outcomes, K quality seemed to have a more prominent effect. Specifically, we found that higher K-quality is associated with higher K reading scores for those who did not go to pre-K. Also, K quality interacted with LEP status rather than the economic disadvantage status as with pre-K status.

Namely, higher K reading and mathematics scores are expected for LEP students those who were in high-quality K classrooms. This result is in line with Bassok et al.'s (2019) finding that preschool advantage was higher among Black and Hispanic preschool participants. We would like to emphasize that in our sample, being LEP student is strongly associated with Hispanic ethnicity, which accounts for the 75% of the student sample. Thus, this finding is thought to be important since it shows the promising positive effects of having a high-quality K education for the majority of the sample identified as students of color and English language learners.

Conclusion

The findings from this study have several important implications for pre-K and K classroom settings. First, pre-K programs should be necessary for economically disadvantaged students to improve their K readiness and end of K achievement. Second, high-quality K classrooms might help limited English-proficient students to have better mathematics and reading performance. Third, the average lower performance among LEP students implies a concern about what the educators and schools should think about assessing these minority racial students (language, style, etc.) and how we can do better to help them to improve their academic performance.

References

Ansari, A., & Pianta, R. C. (2018). Variation in the long-term benefits of child care: The role of classroom quality in elementary school. *Developmental Psychology*, *54*(10), 1854–1867. https://doi.org/10.1037/dev0000513

Ansari, A., & Winsler, A. (2013). Stability and sequence of center-based and family childcare: Links with low-income children's school readiness. *Children and Youth Services Review*, *35*(2), 358–366. https://doi.org/10.1016/j.childyouth.2012.11.017

Bassok, D., Gibbs, C. R., & Latham, S. (2019). Preschool and children's outcomes in elementary school: Have patterns changed nationwide between 1998 and 2010? *Child Development*, *90*(6), 1875–1897. https://doi.org/10.1111/cdev.13067

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

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

DeAngelis, C. A., Holmes Erickson, H., & Ritter, G. W. (2020). What's the state of the evidence on pre-K programmes in the United States? A systematic review. *Educational Review*, *72*(4), 495–519. https://doi.org/10.1080/00131911.2018.1520688

Durkin, K., Lipsey, M. W., Farran, D. C., & Wiesen, S. E. (2022). Effects of a statewide pre-Kindergarten program on children's achievement and behavior through sixth grade. *Developmental Psychology*, *58*(3), 470–484. https://doi.org/10.1037/dev0001301

Hlavac, M. (2022). *Stargazer: Well-Formatted regression and summary statistics tables. R package version 5.2.3.* https://CRAN.R-project.org/package=stargazer

Lipsey, M. W., Farran, D. C., & Durkin, K. (2018). Effects of the Tennessee prekindergarten program on children's achievement and behavior through third grade. *Early Childhood Research Quarterly*, *45*, 155–176. https://doi.org/10.1016/j.ecresq.2018.03.005

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

Pianta, R. C., Hamre, B. K., & Allen, J. P. (2012). Teacher-Student Relationships and Engagement: Conceptualizing, Measuring, and Improving the Capacity of Classroom Interactions. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 365–386). Springer US. https://doi.org/10.1007/978-1-4614-2018-7_17

R Core Team. (2018). *R: A language and environment for statistical computing* [Manual]. R Foundation for Statistical Computing. https://www.R-project.org/

Robson, K., & Pevalin, D. (2016). *Multilevel modeling in plain language*. SAGE Publications Ltd. https://doi.org/10.4135/9781473920712

Sanborn, R., McConnell, K., Kimball, M., Canales, A., Davila, J., Everitt, S., O'Quinn, K., Treacy, C., & Villegas, C. (2016). Pre-k in Texas: A critical component for academic success. *Journal of Applied Research on Children*, *7*(2).

Yoshikawa, H., Weiland, C., & Brooks-Gunn, J. (2016). When does preschool matter? *The Future of Children*, *26*(2), 21–36.

Appendix

Table 1
Data set description.

Data columns	Description
kindergarten reading score	Original percentile reading scores (1-100) (Standardized)
kindergarten mathematics score	Original percentile mathematics scores (1-100) (Standardized)
kindergarten classroom quality	Continuous quality score of K-classrooms
pre-K classroom quality	No PK, LQ PK, and HQ PK
No_PK_Dum	Dummy variable based on pre-K classroom quality LQ PK as the reference
HQ_PK_Dum	Dummy variable based on pre-K classroom quality
Hisp_Dum	Dummy variable for Hispanic Reference group is Black students
White_Dum	Dummy variable for White
Other_Dum	Dummy variable for Other Ethnicity
MALE	0=Female, 1=Male
LEP (Limited English Proficient) indicator	0=No, 1=Yes
ECON_DIS (Economically disadvantaged) indicator	0=No, 1=Yes

Table 2

Descriptive statistics of variables.

Variables	Levels	f	%
Ethnicity	Black	423	(21.6%)
	Hispanic	1,463	(74.3%)
	White	61	(3%)
	Other	22	(1.1%)
MALE	Yes	950	(48.2%)
	No	1,019	(51.8%)
LEP	Yes	1,133	(57.5%)
	No	836	(42.5%)
ECON_DIS	Yes	1,734	(88.1%)
	No	235	(11.9%)
ECON_DIS			
Yes (Ethnicity)	Black	382	(22.0%)
	Hispanic	1,301	(75.0%)
	White	33	(2.0%)
	Other	18	(1.0%)
ECON_DIS			
No (Ethnicity)	Black	41	(17.5%)
	Hispanic	162	(68.9%)
	White	28	(11.9%)
	Other	4	(1.7%)
Pre-K quality	HQ PK	525	(26.7%)
	LQ PK	896	(45.5%)
	No PK	548	(27.8%)
k_{com}	(statistics)		
	Mean	0.00	
	SD	1.00	
	Range	5.43 (-3.17-2.27)	

Table 3

Model fitting results for two dependent variables.

Models	Predictors	AIC	BIC	R2 (cond.)	R2 (marg.)	ICC	RMSE
Mathematics score							
Baseline model		5,131.0	5,147.7	0.19	0	0.19	0.81
Model 1	+ Ethnicity,Gender, ECON-DIS,LEP	5,107.4	5,157.7	0.21	0.02	0.19	0.8
Model 2	+ pre-K classroom quality indicator	5,069.2	5,130.6	0.23	0.04	0.2	0.79
Model 3	$+k_{com}$	5,067.1	5,134.1	0.23	0.04	0.19	0.79
Model 4	+ interaction of pre-K classroom quality indicator and k_{com}	5,070.4	5,148.5	0.23	0.04	0.19	0.79
Model 5	+ interaction of pre-K classroom quality indicator and k_{com} with ECON-DIS,LEP	5,060.8	5172.5	0.23	0.06	0.19	0.79
Reading score							
Baseline model		5,592.1	5,608.9	0.18	0	0.18	0.91
Model 1	+ Ethnicity,Gender, ECON-DIS,LEP	5,542.2	5,592.5	0.18	0.04	0.15	0.91
Model 2	+ pre-K classroom quality indicator	5,521.6	5,583.0	0.19	0.05	0.15	0.9
Model 3	$+k_{com}$	5,520.8	5,587.8	0.2	0.06	0.15	0.9
Model 4	+ interaction of pre-K classroom quality indicator and k_{com}	5,522.1	5,600.2	0.2	0.06	0.15	0.9
Model 5	+ interaction of pre-K classroom quality indicator and k_{com} with ECON-DIS,LEP	5,513.2	5,624.9	0.21	0.07	0.15	0.89

Note:

AIC: Akaike Information Criterion; BIC: Bayesian Information Criterion; R2: the coefficient of determination (R-squared); ICC: Intraclass Correlation Coefficient; RMSE: Root Mean Square Error

Table 4

Model estimates of best fit two models.

	Dependent variable:	
	Kindergarten mathematics score	Kindergarten reading score
Constant β_{00}	−0.065	0.622***
(Intercept)	(−0.243, 0.113)	(0.424, 0.819)
Hisp_Dum β_{01}	0.251***	0.145*
	(0.139, 0.362)	(0.022, 0.269)
White_Dum β_{02}	0.196	0.184
	(−0.022, 0.413)	(−0.061, 0.428)
Other_Dum β_{03}	0.301	0.180
	(−0.017, 0.618)	(−0.177, 0.538)
MALE β_{04}	−0.059	−0.250***
	(−0.122, 0.004)	(−0.320, −0.179)
LEP β_{05}	−0.282***	0.262***
	(−0.413, −0.152)	(0.119, 0.406)
No_PK_Dum β_{07}	0.236	0.175
	(−0.004, 0.476)	(−0.095, 0.445)
k_com γ_{01}	−0.007	−0.161*
	(−0.133, 0.118)	(−0.299, −0.023)
HQ_PK_Dum β_{08}	0.293*	−0.021
	(0.040, 0.546)	(−0.306, 0.263)
ECON_DIS β_{06}	0.113	−0.006
	(−0.038, 0.263)	(−0.175, 0.163)
No_PK_Dum:k_com β_{09}	0.052	0.108**
	(−0.026, 0.130)	(0.020, 0.195)
k_com:HQ_PK_Dum β_{10}	0.007	0.064
	(−0.083, 0.097)	(−0.037, 0.164)
No_PK_Dum:ECON_DIS β_{11}	−0.557***	−0.422**
	(−0.801, −0.312)	(−0.697, −0.147)
HQ_PK_Dum:ECON_DIS β_{12}	−0.283*	0.046
	(−0.528, −0.037)	(−0.231, 0.323)
k_com:ECON_DIS β_{13}	−0.005	0.092
	(−0.114, 0.104)	(−0.030, 0.215)
LEP:No_PK_Dum β_{14}	−0.053	−0.099
	(−0.214, 0.109)	(−0.281, 0.083)
LEP:HQ_PK_Dum β_{15}	−0.091	−0.107
	(−0.271, 0.089)	(−0.308, 0.093)
LEP:k_com β_{16}	0.145**	0.199***
	(0.047, 0.243)	(0.094, 0.304)
Random effects:		
Intercept γ_{00}	S.D.: 0.393	S.D.: 0.387
Residual μ_{0j}	S.D.: 0.816	S.D.: 0.924

Note: *p<0.1; **p<0.05; ***p<0.01
() 95% confidence interval