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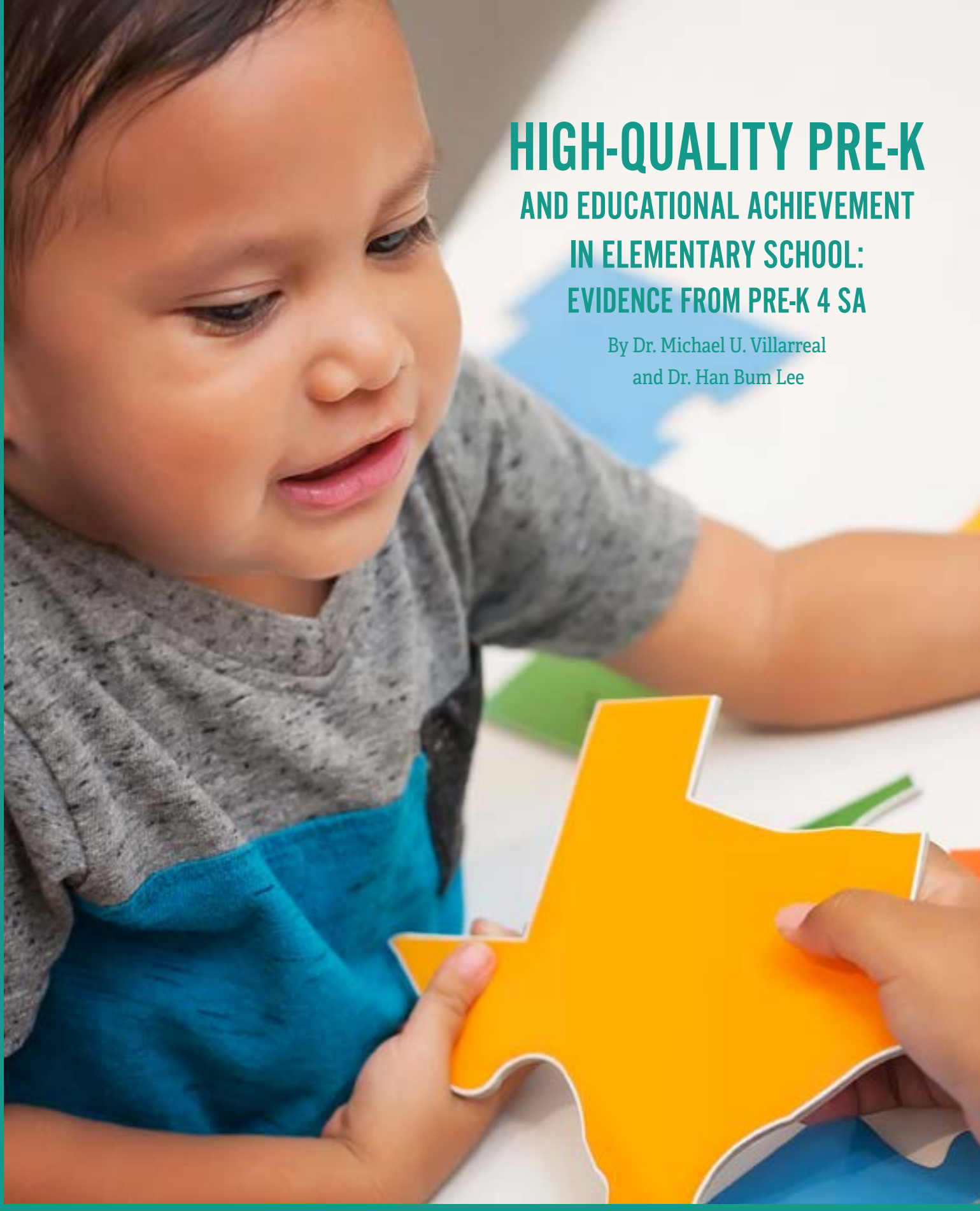

HIGH-QUALITY PRE-K AND EDUCATIONAL ACHIEVEMENT IN ELEMENTARY SCHOOL: EVIDENCE FROM PRE-K 4 SA

By Dr. Michael U. Villarreal
and Dr. Han Bum Lee

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EXECUTIVE SUMMARY

This study examined the academic and social impact of attending Pre-K 4 SA, a high-quality public pre-Kindergarten (pre-K) program in San Antonio, relative to other local public pre-K programs. It expands on an earlier study by including two additional pre-K cohorts and extending the analysis of future outcomes up to fifth grade. In summary, this study investigated the following questions:

1. Did Pre-K 4 SA improve students' academic performance relative to other public pre-k programs from third to fifth grade?
2. Did Pre-K 4 SA cause changes in students' behavioral outcomes relative to other public pre-k programs in third to fifth grade?
3. Relative to other public pre-k programs in third to fifth grade, did fewer Pre-K 4 SA students receive special education services?
4. Relative to other public pre-k programs, did Pre-K 4 SA students demonstrate academic outcomes that became stronger in later cohorts as the program matured?

KEY FINDINGS

- **Before the first year of COVID, Pre-K 4 SA students in third and fourth grade realized meaningful gains in reading and math performance relative to their quasi-control group.**

- **After the first year of COVID, Pre-K 4 SA students in fourth and fifth grade (the only grades tested for which this study has data) realized meaningful gains in math performance relative to their quasi-control group, but not in reading.**

- **Pre-K 4 SA students had statistically equivalent rates of attendance and school disciplinary reports received as their quasi-control group, respectively.**

- **The first cohort of Pre-K 4 SA students had a higher probability of receiving special education services than their quasi-control group in third to fifth grade. However, this statistically significant relationship vanished for the second and third cohorts of Pre-K 4 SA students.**

- **This study could not observe Pre-K 4 SA impacts as the program matured because the COVID-19 pandemic occurred during the study period, confounding the comparison of effect sizes per grade across the cohorts.**

POLICY IMPLICATIONS

Pre-K 4 SA's effectiveness has policy implications for funding agencies because of the size of its impact and lasting effects on student learning. Pre-K 4 SA's demonstrated impact should compel state officials to consider restoring funds previously cut from public school budgets that targeted academically at-risk students and rededicate these funds to allow public pre-K to meet national quality standards, similar to Pre-K 4 SA. (See Villarreal & Lee (2021) for these quality standards.)

Second, local school districts should consider how they could afford to replicate Pre-K 4 SA's approach to pre-kindergarten. They could start with identifying existing interventions that serve similar populations and compare their effectiveness and costs to Pre-K 4 SA. In making this comparison, local education leaders should consider the full cost of less effective interventions that target older age groups, including the economic, social, and psychological cost born by children.

INTRODUCTION

US children enter the world into unequal circumstances. Nearly one in five US children under the age of five (or 19.1%) live in poverty. And in some neighborhoods in urban counties, such as Bexar County, this figure rises above 60% (US Census, 2022). Being born into poverty puts the American dream out of reach of too many children at the start of their lives.

One solution that has been found to mitigate the harms of childhood poverty is early childhood education (ECE). The weight of scientific research has found that high-quality pre-Kindergarten (pre-K) can produce large effects that help close gaps in childhood development experienced by poor children. In a meta-analysis of 22 high-quality experimental and observational studies conducted between 1960 and 2016, McCoy and co-authors (2017) found that ECE participation reduced the probability of special education placement and grade retention by an averaged effect size of 0.33 standard deviations (or 8.1 percentage points) and 0.26 standard deviations (or 8.3 percentage points). Barnett et al. (2018) found that public pre-K improved student performance on language, math, and literacy test scores by averaged effect sizes of 0.24, 0.44, and 1.10 standard deviations, respectively.

In a random assignment experiment of long-term pre-K effects, Heckman et al. (2010) found that high-quality pre-K caused higher levels of educational achievement, greater economic mobility, and more pro-social behaviors, such as the avoidance of crime and independence from the need for government support. They also estimated that high-quality pre-K produced a return of between $7 and $12 to society for each $1 invested. Moreover, students historically underserved by educational institutions (e.g., dual language learners and children from low-income families) were found to benefit more from high-quality pre-K (Ansari et al., 2021).

Though many studies have produced evidence supporting pre-K attendance, some have raised questions about the generalizability of the findings. Some studies have found that children's initial gains during pre-K diminished or even disappeared after preschool (e.g., Bailey et al., 2017; Durlak et al., 2011). Another set of studies has argued that pre-K benefits rely heavily on the program's quality and question if quality programs can be scaled (e.g., Magnuson et al., 2007; Weiland et al., 2013; Valentino, 2018). This last concern has significant policy implications for the US.

According to the State of Preschool 2019, only 8% of US children enrolled in public pre-K programs that met 9 or 10 quality standards set by the National Institute for Early Education Research (NIEER); while 40% of children were served in programs that met four or fewer quality standards (Friedman-Krauss et al., 2020). Texas's public pre-K programs met three quality standards (Friedman-Krauss et al., 2020). Taken together, these findings suggest that most Texas children are not receiving the full and lasting benefits of high-quality pre-K (Villarreal & Lee, 2021).

With this concern in mind, community and business leaders of San Antonio launched a campaign to expand access to high-quality pre-K in San Antonio. Voters twice ratified a program that includes four high-quality pre-K lab schools, named Pre-K 4 SA, in each city quadrant (Villarreal & Lee, 2021). By design, Pre-K 4 SA meets all 10 quality standards. The main purpose of this study was to update a previous study of Pre-K 4 SA's impact on students' educational outcomes in elementary school. This study expanded the scope of UEI's earlier evaluation work of Pre-K 4 SA by including two cohorts beyond the program's inaugural cohort of 2014 and following their educational outcomes up to six years from pre-K graduation (or up to fifth grade).

DATA

This study used data from Texas's statewide longitudinal data system (SLDS) operated by the University of Texas at Austin Educational Research Center (ERC). The SLDS system maintains longitudinal datasets containing a broad range of student and school characteristics from pre-K to higher education. The data used in this study were initially collected by public schools and then reported to the Texas Education Agency (TEA). We also used administrative data provided by Pre-K 4 SA, which identified Pre-K 4 SA students and their pre-k schools. Availability of the outcome variables varied by cohort based on their established history and data availability. For example, fifth-grade test scores were not included in this study for the pre-K cohort of 2015/2016 because 2022 data has not been made available.

DATA LIMITATIONS DUE TO COVID-19

The COVID-19 pandemic impacted this study's access to data, as shown in Table 1. The pandemic caused the state to suspend the STAAR test as a statewide mandate in the Spring of 2020. As a result, third and fourth grade STAAR test scores were only available for the first cohort. Third and fifth grade STAAR test scores were only available for the second cohort. And, only fourth grade STAAR test scores were available for the third cohort.

TABLE 1: DATA AVAILABILITY OF EDUCATIONAL OUTCOMES BY STUDY COHORT

POLICY BENCHMARK	PRE-K	3RD GRADE	4TH GRADE	5TH GRADE
1st cohort **School Year** **Data Availability**	2013/14	2017/18 Academic (0) Behavior (0)	2018/19 Academic (0) Behavior (0)	2019/20 Academic (x) Behavior (0)
2nd cohort **School Year** **Data Availability**	2014/15	2018/19 Academic (0) Behavior (0)	2019/20 Academic (x) Behavior (0)	2020/21 Academic (0) Behavior (x)
3rd cohort **School Year** **Data Availability**	2015/16	2019/20 Academic (x) Behavior (0)	2020/21 Academic (0) Behavior (x)	

Notes. 0 - ERC data were available at the time of the analysis; x - ERC data were not available at the time of analysis.

The pandemic also delayed TEA in its release of testing data. TEA has yet to release sixth grade STAAR test scores as of this writing. They also have not provided data on behavioral outcomes for the second cohort's fifth grade and the third cohort's fourth and fifth grades. Consequently, one of this study's research questions related to Pre-K 4 SA's impact as the program matures could not be answered due to COVID's confounding effects.

RESEARCH DESIGN

Data alone does not determine the validity of an empirical study, especially one attempting to identify causal relationships. Reliable data plus a research design appropriate to the study's research questions determine the validity of the study's research findings. This study used a quasi-experimental research design involving a technic known as instrumental variable analysis to identify Pre-K 4 SA's effect on student outcomes.

The most effective method for identifying a causal relationship between an intervention (such as enrollment in Pre-K 4 SA) and an outcome of interest (e.g., performance on a math exam) is to randomly assign students to a treatment group that receives the intervention and a control group that does not receive the intervention and then observe the difference in the average outcomes of the two groups (i.e., the treatment group's average math score minus the control groups' average math score).

In studying the effects of education interventions, most research teams have no ability to randomly assign students to treatment and control groups. They only have access to data after events have played out (e.g., after voluntary

pre-k enrollment and after math exams have been completed). However, in the case of instrumental variable analysis, a research team has the fortune of discovering an instrumental variable (IV) that acts like an instrument of random assignments, such as a lottery system, in that it predicts who receives treatment and is uncorrelated with the outcomes of interest. In this study, researchers discovered an instrumental variable.

This study's instrumental variable was the aggregated distance between a student's assigned school district in pre-k and each of the four Pre-K 4 SA lab schools. This variable predicted enrollment in Pre-K 4 SA. As it decreased, the likelihood of Pre-K 4 SA enrollment increased; and vice versa. Furthermore, this distance variable was not correlated with performance on STAAR exams or any of this study's outcomes of interest. Because this variable functioned like a random assignment mechanism, it allowed for the identification of Pre-K 4 SA's effects while mitigating the influence of self-selection bias and other types of endogeneity.

STUDY LIMITATIONS

Quasi-experimental research designs, like the one used in this study, have weaker internal validity than true experiments with random assignment of subjects. In particular, unobserved data limits all studies that work with observational data. For example, this study did not directly measure each student's grit, perseverance, and passion for long-term goals in estimating pre-K effects. If participants in Pre-K 4 SA disproportionately possess grit, and

if the study's control variables were poor proxies for grit, then grit might be a confounding variable. If this was the case, then not controlling for grit would cause Pre-K 4 SA effects to be overstated. Of course, there might also be other lurking factors that could bias effect sizes downward. Because these variables were unobserved, their confounding effects could not be entirely dismissed, only mitigated through research design, methodology, and data.

This study was also limited by data limitations related to attrition and precise home addresses of students. More information on this study's research design and study limitations can be found in Appendix A.

STUDY POPULATION

The study population was represented by four-year-old children of Bexar County who were eligible for public pre-K. The study sample was defined by all students who attended public pre-K programs in 2012/13 (first cohort), 2013/14 (second cohort), and 2014/15 (third cohort) in Bexar County. Students who attended Pre-K 4 SA were considered part of the quasi-treatment group; while, students who attended public pre-K programs other than Pre-K 4 SA in Bexar County were defined as the quasi-control group. We excluded students who did not have public pre-K and public elementary school records at Bexar County schools. We also excluded from the quasi-control group students who attended charter schools for pre-K or elementary school because of missing student residential information. [1]

The total sample size of the quasi-treatment group amounted to 1,778 (352 students for the first cohort, 640 students for the second cohort, and 774 students for the third cohort). Similarly, the total sample size of the quasi-control group amounted to 9,998 for the first cohort, 9,208 students for the second cohort, and 8,590 for the third cohort.

1 This study utilized students' residential information as an IV to address potential selection issues surrounding students' Pre-K 4 SA enrollment and educational outcomes in elementary school. Excluding study observations that lacked residential information would improve the study's internal validity at the expense of external validity. We performed a statistical test investigating potential attrition bias in estimation and discussed the results in the study limitation section.

DESCRIPTIVE STATISTICS OF STUDY'S CONTROL VARIABLES

The study's research design controlled for student characteristics that existed prior to or at initial enrollment into pre-K. These controls included gender, race and ethnic group, homelessness, and eligibility for the federal free-or-reduced-price lunch program. They also included indicators of limited English proficiency (LEP) and receipt of special education services in pre-K.

Descriptive statistics of control variables identified variation between the treatment and quasi-control groups by cohort, as shown in Table 2. On average, Pre-K 4 SA served a lower proportion of LEP students and special education students compared to those of other local public pre-K programs. For the third cohort, Pre-K 4 SA served a lower proportion of students who received free- or reduced-price lunch, LEP students, and special education students relative to other local public pre-K programs. The second cohort of Pre-K 4 SA comprised a slightly higher proportion of African American students but a lower proportion of LEP and special education students than the quasi-control group.

TABLE 2: DESCRIPTIVE STATISTICS OF STUDY'S CONTROL VARIABLES

	1ST COHORT			2ND COHORT			3RD COHORT		
	Pre-K 4 SA	Control Group	Diff.	Pre-K 4 SA	Control Group	Diff.	Pre-K 4 SA	Control Group	Diff.
Female	0.466	0.484	-0.018	0.482	0.487	-0.005	0.479	0.495	-0.016
	(0.500)	(0.500)	[0.027]	(0.500)	(0.500)	[0.020]	(0.500)	(0.500)	[0.018]
African American	0.057	0.062	-0.005	0.078	0.060	0.019*	0.077	0.066	0.012
	(0.232)	(0.241)	[0.013]	(0.269)	(0.237)	[0.010]	(0.267)	(0.248)	[0.009]
Hispanic	0.855	0.856	-0.001	0.834	0.844	-0.010	0.839	0.828	0.011
	(0.352)	(0.351)	[0.019]	(0.372)	(0.363)	[0.014]	(0.368)	(0.377)	[0.014]
Economically Disadvantaged	0.918	0.935	-0.017	0.899	0.909	-0.009	0.853	0.899	-0.046***
	(0.275)	(0.247)	[0.013]	(0.301)	(0.288)	[0.011]	(0.355)	(0.302)	[0.011]
Homeless	0.017	0.018	-0.001	0.021	0.022	-0.001	0.012	0.019	-0.007
	(0.130)	(0.133)	[0.007]	(0.142)	(0.147)	[0.006]	(0.110)	(0.136)	[0.005]
LEP	0.108	0.254	-0.146***	0.062	0.254	-0.192***	0.143	0.256	-0.114***
	(0.311)	(0.435)	[0.023]	(0.242)	(0.435)	[0.017]	(0.350)	(0.437)	[0.016]
Special Education	0.011	0.049	-0.037***	0.018	0.044	-0.027***	0.020	0.052	-0.032***
	(0.106)	(0.215)	[0.012]	(0.132)	(0.206)	[0.008]	(0.139)	(0.221)	[0.008]
Distance to Pre-K 4 SA	0.580	0.669	-0.090***	0.602	0.663	-0.061***	0.595	0.661	-0.066***
	(0.298)	(0.337)	[0.018]	(0.328)	(0.336)	[0.013]	(0.329)	(0.338)	[0.012]
Observations	352	9,998	10,350	640	9,208	9,848	774	8,590	9,364

Notes. Standard deviations are in parentheses. Standard errors are in brackets. *p < .10. **p < .05. ***p < .01.

FINDINGS

This study analyzed Pre-K 4 SA's impact on reading and math test scores by using the raw number of points earned on an exam and the standardized transformation of raw scores (i.e., z-scores). Standardized effect sizes were produced to allow readers to compare effect sizes across outcomes and interventions.

PRE-K 4 SA IMPACTS ON READING AND MATH TEST SCORES IN THIRD GRADE

As presented in Table 3, the first cohort of Pre-K 4 SA students achieved higher STAAR reading test scores by 3.1 points relative to students who attended other local public pre-K programs. That is, students by attending Pre-K 4 SA increased 0.46 standard deviations in reading scores relative to the quasi-control group. We also found a larger Pre-K 4 SA effect for the second cohort of students, which had a gain of 0.6 standard deviations (or 4.4 points) in reading. Additionally, Pre-K 4 SA caused an increase of 0.66 (or 4.7 points) and 0.41 (or 2.8 points) standard deviations in STAAR math test scores for its' first and second cohorts of students, respectively, compared to their counterparts.

TABLE 3: IMPACTS OF PRE-K 4 SA ON STAAR READING AND MATH SCORES IN THIRD GRADE

	READING				MATH			
	1st Cohort		2nd Cohort		1st Cohort		2nd Cohort	
	Raw Score	Standard-ized Score	Raw Score	Standard-ized Score	Raw Score	Standard-ized Score	Raw Score	Standard-ized Score
Pre-K 4 SA	3.191***	0.459***	4.376***	0.601***	4.727***	0.658***	2.775***	0.413***
	(0.992)	(0.143)	(0.954)	(0.131)	(0.985)	(0.137)	(0.641)	(0.095)
CG Mean	20.794	-0.018	20.639	-0.047	19.465	-0.013	20.208	-0.014
Distance to Pre-K 4 SA	-0.387***		-0.308***		-0.436***		-0.299***	
	(0.079)		(0.065)		(0.080)		(0.066)	
/athrho	-0.176***		-0.266***		-0.279***		-0.191***	
	(0.056)		(0.061)		(0.052)		(0.040)	
/Insigma	-0.025***		-0.020***		-0.013**		-0.021***	
	(0.006)		(0.007)		(0.006)		(0.006)	
Wald X^2	9.90***		19.19		28.62***		22.94***	
	[0.002]		[<0.001]		[<0.001]		[<0.001]	
Observations	9,593		9,276		9,595		9,280	

Notes. CG – quasi-control group. Distance to Pre-K 4 SA coefficient was obtained from the 1st stage regression. The results of other control variables in the 1st and 2nd stage regressions were omitted due to space. Robust standard errors are in parentheses. P-values are in brackets.
*p < .10. **p < .05. ***p < .01.

PRE-K 4 SA IMPACTS ON READING AND MATH TEST SCORES IN FOURTH AND FIFTH GRADES

As shown in Table 4, the first cohort of Pre-K 4 SA students was predicted to achieve higher reading and math test scores by 4.6 and 4.9 points, respectively, which were equivalent to an increase of 0.62 and 0.66 standard deviations in reading and math test scores relative to the quasi-control group students. In addition, the impact of Pre-K 4 SA on reading and math test scores in fourth grade was greater than third grade, indicating that academic impacts of Pre-K 4 SA were sustained and even growing for an additional year.

In contrast to evidence that the first cohort of Pre-K 4 SA students experienced increased reading test scores in fourth grade, we found no significant impact of Pre-K 4 SA on fourth-grade reading test scores of the third cohort. Furthermore, no score gain in the fifth-grade reading test was found for the second cohort (Table 5). It is noteworthy that, unlike the first cohort of students, the latter two cohorts of students took their fourth- and fifth-grade STAAR tests during the Covid-19 Pandemic. During this period in San Antonio, many schools and districts supplemented or even replaced face-to-face teaching with digital learning tools that not all teachers were well positioned to provide online classes (UEI, 2020a). Moreover, parents and children appealed to various technical and financial challenges with distance learning (UEI, 2020b). Or, as previous studies asserted (e.g., Bailey et al., 2017; Durlak et al., 2011), the ability students gained in Pre-K 4 SA might disappear in fourth or fifth grade for these cohorts. Taken together, it might be reasonable to explain that overall students' academic performance in reading decreased during the pandemic, and Pre-K 4 SA students were hit harder than their counterparts.

TABLE 4: IMPACTS OF PRE-K 4 SA ON STAAR READING AND MATH TEST SCORES IN FOURTH GRADE

	READING				MATH			
	1st Cohort		3rd Cohort		1st Cohort		3rd Cohort	
	Raw Score	Standardized Score	Raw Score	Standardized Score	Raw Score	Standardized Score	Raw Score	Standardized Score
Pre-K 4 SA	4.660***	0.624***	0.293	0.031	4.918***	0.655***	3.198*	0.373*
	(1.093)	(0.146)	(0.937)	(0.098)	(1.499)	(0.200)	(1.642)	(0.061)
CG Mean	21.707	-0.025	16.970	-0.003	19.884	-0.003	13.453	-0.031
Distance to Pre-K 4 SA	-0.395***		-0.263***		-0.407***		-0.295***	
	(0.078)		(0.062)		(0.080)		(0.062)	
/athrho	-0.253***		0.019		-0.282***		-0.185*	
	(0.062)		(0.045)		(0.091)		(0.098)	
/Insigma	-0.024***		-0.017***		-0.032***		-0.015*	
	(0.006)		(0.006)		(0.007)		(0.008)	
Wald X^2	16.51***		0.19		9.55***		3.59*	
	[<0.001]		[0.666]		[0.002]		[0.058]	
Observations	9,397		8,642		9,352		8,638	

Notes. CG – quasi-control group. Distance to Pre-K 4 SA coefficient was obtained from the 1st stage regression. The results of other control variables in the 1st and 2nd stage regressions were omitted due to space. Robust standard errors are in parentheses. P-values are in brackets.
*p < .10. **p < .05. ***p < .01.

TABLE 5: IMPACTS OF PRE-K 4 SA ON STAAR READING AND MATH TEST SCORES IN FIFTH GRADE

	READING 2nd Cohort		MATH 2nd Cohort	
	Raw Score	Standardized Score	Raw Score	Standardized Score
Pre-K 4 SA	-0.791	-0.072	1.845*	0.185*
	(0.987)	(0.090)	(1.020)	(0.055)
CG Mean	20.342	0.012	16.137	-0.002
Distance to Pre-K 4 SA	-0.293***		-0.299***	
	(0.065)		(0.065)	
/athrho	0.030		-0.099**	
	(0.040)		(0.046)	
/Insigma	-0.030***		-0.026***	
	(0.006)		(0.006)	
Wald X^2	0.59		4.61**	
	[0.442]		[0.032]	
Observations	8,895		8,888	

Notes. CG – quasi-control group. Distance to Pre-K 4 SA coefficient was obtained from the 1st stage regression. The results of other control variables in the 1st and 2nd stage regressions were omitted due to space. Robust standard errors are in parentheses. P-values are in brackets. *p < .10. **p < .05. ***p < .01.

In contrast, Pre-K 4 SA students achieved higher math test scores even during the Covid-19 Pandemic. Specifically, the third cohort of Pre-K 4 SA students had higher fourth-grade math test scores by 3.1 points than the quasi-control group students, which were equivalent to an increase of 0.37 standard deviations. Similarly, the second cohort of Pre-K 4 SA students experienced an increase of 0.19 standard deviations in fifth-grade math test scores relative to the quasi-control group.

Impacts on Behavioral Outcomes in Three to Five Years of Elementary School

Tables 6 and 7 present the impact of Pre-K 4 SA on behavioral outcomes compared to the quasi-control group who attended other local public pre-K programs. The results showed that the first cohort of Pre-K 4 SA students was predicted to have a higher probability of receiving special education by around 10 percentage points than the quasi-control group in three to five years of elementary school. Pre-K 4 SA appeared to not make a meaningful difference in other behavioral outcomes at school across the cohorts, except that the third cohort of Pre-K 4 SA students had a 1 percent higher attendance rate than their quasi-control group.

VALIDITY OF INSTRUMENTAL VARIABLE

Distance to Pre-K 4 SA centers was statistically significant and negatively associated with students' enrollment in Pre-K 4 SA over assigned neighborhood pre-K. The statistical significance of test statistics (ρ and Wald test), presented in Tables 3-7, affirmed the validity of the IV estimator. For example, the negative ρ indicated that unobservable characteristics that increased the test scores tended to decrease the likelihood that children attended Pre-K 4 SA. This pattern meant that the IV analysis mitigated the influence of selection bias.

TABLE 6: IMPACTS OF PRE-K 4 SA ON BEHAVIORAL OUTCOMES IN THREE YEARS OF ELEMENTARY SCHOOL

	1ST COHORT			2ND COHORT			3RD COHORT		
	Attendance Rates	Disciplinary Action	Special Education	Attendance Rates	Disciplinary Action	Special Education	Attendance Rates	Disciplinary Action	Special Education
Pre-K 4 SA	0.003	0.642	1.017***	-0.001	0.842	0.429	0.010***	0.537	0.297
	(0.005)	(0.849)	(0.344)	(0.003)	(0.621)	(0.399)	(0.003)	(0.525)	(0.434)
M.E.		0.071	0.093		0.080	0.068		0.054	0.058
CG Mean	0.945	0.084	0.097	0.940	0.075	0.137	0.943	(0.064)	(0.134)
Distance to Pre-K 4 SA	-0.357***	-0.389***	-0.402***	-0.271***	-0.275***	-0.277***	-0.276***	-0.278***	-0.274***
	(0.072)	(0.070)	(0.070)	(0.061)	(0.060)	(0.061)	(0.058)	(0.058)	(0.058)
/athrho	-0.029	-0.272	-0.368**	-0.013	-0.395	-0.221	-0.045***	-0.224	-0.069
	(0.025)	(0.366)	(0.148)	(0.017)	(0.307)	(0.190)	(0.012)	(0.256)	(0.215)
/Insigma	-2.912***			-2.821***			-2.851***		
	(0.015)	0.552	6.200**	(0.016)	1.661	1.349	(0.027)	0.767	0.104
Wald X^2	1.36	[0.458]	[0.013]	0.64	[0.197]	[0.246]	13.24***	[0.381]	[0.747]
	[0.244]	10,350	10,350	[0.424]	9,848	9,848	[<0.001]	9,364	9,364
Observations	10,350	9,998	10,350	9,848	9,208	9,848	9,364	8,590	9,364

Notes. CG – quasi-control group. M.E. denote marginal effect. Distance to Pre-K 4 SA coefficient was obtained from the 1st stage regression. The results of other control variables in the 1st and 2nd stage regressions were omitted due to space. Robust standard errors are in parentheses. P-values are in brackets.. *p < .10. **p < .05. ***p < .01.

TABLE 7: IMPACTS OF PRE-K 4 SA ON BEHAVIORAL OUTCOMES IN FOUR AND FIVE YEARS OF ELEMENTARY SCHOOL

	IN 4 YEARS						IN 5 YEARS		
	1ST COHORT			2ND COHORT			1ST COHORT		
	Attendance Rates	Disciplinary Action	Special Education	Attendance Rates	Disciplinary Action	Special Education	Attendance Rates	Disciplinary Action	Special Education
In 4 Years Pre-K 4 SA	0.002	0.792	1.003***	0.002	0.570	0.559	0.004	0.836	0.774*
	(0.006)	(0.691)	(0.377)	(0.003)	(1.005)	(0.407)	(0.004)	(0.678)	(0.419)
M.E.		0.099	0.098		0.073	0.094		0.136	0.100
CG Mean	0.945	0.117	0.121	0.943	0.097	0.156	0.948	0.147	(0.150)
Distance to Pre-K 4 SA	-0.359***	-0.389***	-0.405***	-0.272***	-0.269***	-0.279***	-0.350***	-0.379***	-0.392***
	(0.073)	(0.069)	(0.070)	(0.061)	(0.060)	(0.060)	(0.073)	(0.071)	(0.071)
/athrho	-0.010	-0.362	-0.426**	-0.023	-0.283	-0.290	-0.024	-0.352	-0.360**
	(0.038)	(0.308)	(0.167)	(0.015)	(0.486)	(0.198)	(0.026)	(0.309)	(0.183)
/Insigma	-2.969***			-2.894***			-3.063***		
	(0.016)			(0.016)			(0.015)		
Wald X^2	0.06	1.375	6.51**	2.53	0.340	2.15	0.89	1.297	3.839**
	[0.802]	[0.241]	[0.011]	[0.112]	[0.560]	[0.143]	[0.347]	[0.255]	[0.050]
Observations	10,172	10,172	10,172	9,702	9,702	9,702	10,032	10,032	10,032

Notes. CG – quasi-control group. M.E. denote marginal effect. Distance to Pre-K 4 SA coefficient was obtained from the 1st stage regression. The results of other control variables in the 1st and 2nd stage regressions were omitted due to space. Robust standard errors are in parentheses. P-values are in brackets. *p < .10. **p < .05. ***p < .01.

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APPENDIX A

We first constructed the following linear model of academic performance y_i of student *i* who attended public pre-K schools in Bexar County:

$$(1)\quad y_i = \beta_0 + \beta_1 s_i + \beta_2' x_{1i} + \varepsilon_i,$$

where x_{1i} represents a vector of observable characteristics of student *i* in pre-K that would affect his/her academic performance in elementary school, s_i is the binary indicator of attending Pre-K 4 SA, and ε_i is an error term. The parameter of interest is β_1, program effect size. However, the estimation of equation 1 is problematic when endogeneity arises.

Endogeneity can cause estimated program effects (β_1) to be biased when unobserved characteristics are correlated with students' enrollment in Pre-K 4 SA over their assigned neighborhood public pre-K program, while also being correlated with their academic performance in later years.

For example, previous studies found that parents valued a multitude of characteristics when choosing preschools for their children (Grogan, 2012). They often considered a range of educational aspects of care such as the quality of teachers (*i.e.*, educational degree and teaching experience), teacher-child ratio, peer interactions, and school readiness curriculum (*e.g.*, Fuller et al., 1996; Kim & Fram, 2009). However, these preferences were not uniform across all parents.

Highly educated parents tended to place more importance on educational aspects of pre-K programs over convenience factors such as program hours (half-day/full-day), location, and transportation costs (Barbarin et al., 2006; Early & Burchinal, 2001; Johansen et al., 1996; Li-Grining & Coley, 2006).

If factors describing parents' school preference and students' academic ability were not controlled in the model, the impact that Pre-K 4 SA had on student outcomes would be biased by the extent that such omitted factors were positively or negatively correlated with school selection and student outcomes.

To address this endogeneity problem, we used a common approach known as instrumental variable (IV) analysis. We utilized the endogenous treatment effect (ETE) model for continuous outcome variables and the recursive bivariate probit (RBP) model for binary outcome variables.

IDENTIFICATION OF INSTRUMENTAL VARIABLE

A variable that functioned like a random assignment mechanism was needed to implement this study's chosen research method. This variable, known as an instrumental variable, predicts treatment but is unrelated to outcomes of interest. In this study, this variable was the aggregate distance between the geographic center of a student's school district in pre-K and all four Pre-K 4 SA centers.

Theoretically, students who live closer to a Pre-K 4 SA center are more likely to attend Pre-K 4 SA because of lower costs. These children's parents have more ready access to information about Pre-K 4 SA (even if it is just being reminded of

its existence by regularly passing by its location) and lower transportation costs (both direct expenses and the opportunity cost of lost time) with dropping off and picking up children from a Pre-K 4 SA center. These lower costs make Pre-K 4 SA a more appealing option for those that live closer to a Pre-K 4 SA center. Therefore, as the distance between a student's residence (as represented by their school district in pre-K) and Pre-K 4 SA centers decreased, their likelihood of enrolling in Pre-K 4 SA increased. Furthermore, this variable was uncorrelated with student outcomes (e.g., Cullen et al., 2005; Dobbie & Fryer, 2011; Schwartz, 2013).

Distance to Pre-K 4 SA employed a gravitational measure of access that placed less weight on relatively distant locations using a distance decay function, defined as:

$$(2)\ z_{jl} = \sum_{l=1}^{l=4} e^{(-\pi d_{jl})},$$

where d_{jl} is the distance (in kilometers) between the centroid of school district j where a student lived and Pre-K 4 SA center location, l, and π is the distance-decay function. As shown in Table 2, on average, distance to Pre-K 4 SA centers for students who attended Pre-K 4 SA tended to be shorter by 9.2-14% than those who attended other local public pre-K across the cohorts.

STUDY LIMITATIONS

Though this study benefited from a rich collection of student control variables, it also experienced data limitations. First, we limited the study sample to students who attended publicly funded pre-K and elementary schools in Bexar

County. Excluding students outside of this definition cut around 30% of the Pre-K 4 SA study sample, which might harm the generalizability of findings by questioning whether the remaining study sample represented the entire Pre-K 4 SA population (Table 8).

TABLE 8: DATA AVAILABILITY OF EDUCATIONAL OUTCOMES BY STUDY COHORT

	ORIGINAL SAMPLE	NO ELEMENTARY SCHOOL DATA (ATTRITION)	OUT OF BEXAR COUNTY (ATTRITION)	STUDY SAMPLE	SAMPLE REDUCTION
1st cohort	483	46	85	352	-27.1%
2nd cohort	881	83	158	640	-27.4%
3rd cohort	1,139	114	251	774	-32%

Then, the following question would be whether Pre-K 4 SA students who were excluded from the analysis had similar or different characteristics from those who remained in the analysis. We ran a logit regression of attrition–equaled 1 if a study sample was excluded and 0 if otherwise–on a set of student characteristics in pre-K (Table 9). The results showed that African American students were more likely to be in the attrition group for the first cohort, while Hispanic students, LEP students, and special education students were less likely to be in the attrition group for the second cohort. Similarly, for the third cohort, Hispanic students and LEP students were less likely to be in the attrition group.

TABLE 9: LOGIT REGRESSION RESULTS OF STUDENT CHARACTERISTICS IN PRE-K 4 SA DETERMINING SAMPLE

	1ST COHORT	2ND COHORT	3RD COHORT
Female	0.066	0.041	-0.036
	(0.212)	(0.154)	(0.130)
African American	0.942*	-0.307	0.167
	(0.483)	(0.356)	(0.305)
Hispanic	-0.227	-0.560**	0.446**
	(0.373)	(0.250)	(0.215)
Economically Disadvantaged	0.255	0.122	-0.288
	(0.438)	(0.278)	(0.185)
Homeless	0.365	-0.210	-0.087
	(0.365)	(0.575)	(0.561)
LEP	0.446	0.814***	-0.502***
	(0.351)	(0.287)	(0.178)
Special Education	0.823	-0.914***	-.758
	(0.742)	(0.775)	(0.572)
Intercept	-1.263**	-0.715**	-0.230
	(0.498)	(0.340)	(0.245)
Log-likelihood	-272.987	-507.613	-696.239
Pseudo R_2	0.026	0.014	0.020
Observations	483	881	1,139

Notes. Standard deviations are in parentheses. Standard errors are in brackets. *p < .10. **p < .05. ***p < .01.

These results indicated the existence of systematic differences between the attrition and non-attrition groups, opening up the possibility that Pre-K 4 SA might have differential educational impacts for the attrition group. We, therefore, limited the study's findings to students who were found in TEA records and attended, non-charter, public pre-K and elementary schools in Bexar County.

Second, this study lacked students' home addresses, requiring the instrumental variable to be calculated using the distance from the centroid of students' home school district in pre-K grade to the four Pre-K 4 SA locations. This measurement procedure introduced measurement error that increased the further students resided from the center of their school district. Furthermore, lacking students' home addresses also required a second assumption. This study had to assume that Pre-K 4 SA student's home school district in pre-K was the same as in first grade. Because Pre-K 4 SA is an open-enrollment program, students do not need to reside in a particular school district in pre-K. They only need to reside in the City of San Antonio. This was not a strong assumption because less than 10% of students were found to change school districts between pre-k and first grade.

HIGH-QUALITY PRE-K AND EDUCATION ACHIEVEMENT IN ELEMENTARY SCHOOL: EVIDENCE FROM PRE-K 4 SA

By Dr. Michael U. Villarreal
and Dr. Han Bum Lee

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