Greener Grades: The Impacts of Green Schoolyards on Academic Achievement

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ABSTRACT

A large body of literature establishes the link between green space exposure and human health; such spaces have been known to yield benefits such as improving cardiovascular health, mental health, and self-reported general health. Research conducted in school settings hypothesizes that green space may boost academic achievement by improving the physical and emotional health of students. This study examines the impact of school green spaces on standardized English and math scores at 36 public elementary schools in the San Francisco East Bay area. Using a mixed-method approach, I conducted statistical analyses with secondary socio-demographic and geospatial data in addition to carrying out interviews with community stakeholders. My findings suggest that greater levels of disadvantage, an index combining poverty and minority status, is linked to lower academic achievement. Additionally, the more disadvantaged the student body, the fewer trees are found on school grounds. Other common educational determinants such as pupil/teacher ratio, school size, and % female students did not contribute to the greenness-performance link. Within the study sample, school tree cover was the most important predictor of academic performance compared to grass cover. Qualitative data indicate that green space can support child development through pathways of play, learning, and positive behaviors. Future research should be directed towards investigating the short and long-term value of trees in educational settings as well as developing policies to encourage more greening on a state level.

KEYWORDS

education, environmental planning, landscape, children, elementary school

INTRODUCTION

Due to urbanization, the number of people living in cities has increased over the past four decades. However, urbanization has also exacerbated social and health inequities, especially in low-income urban neighborhoods and communities of color (*Hidden Cities* 2010). In the United States, family socioeconomic and demographic characteristics can serve as a direct predictor of a child's educational success. Academic achievement gaps are largest in areas suffering from significant economic disparities since children face barriers to success such as having less experienced instructors, fewer advanced courses, and lower funding for instructional materials (Jao 2018). High-poverty schools also account for the racial disparities in academic achievement, since more minority students are concentrated in these schools (Dobuzinskis 2019). In K-12 public schools in California, Asian Americans, White, and wealthier students tend to perform better than their Black and Hispanic classmates in reading and math. Shockingly, the difference in performance for reading and math between White and Black students is more than two-fold (Cano and Hong, 2020). Since 2020, the COVID-19 pandemic widened opportunity and academic gaps; the disruptions to learning caused grades to plummet across the state for all student groups. In particular, English learners and students from low-income families were most negatively impacted (Kuhfeld et al. 2022). Unequivocal academic performance gaps reflect the extensive unmet needs and untapped potential of low-SES (socioeconomic status) students. Developing strong critical thinking and problem-solving skills will allow children to succeed in school and beyond. In the absence of large-scale, structural solutions to poverty and discrimination, policymakers should consider alternative and low-cost interventions to help urban children reach their full potential. Ultimately, it is important to raise educational achievement among low-income and minority students to enable them to attain greater economic prospects in life and foster intergenerational mobility (García and Weiss 2017).

Urbanization is not only associated with the longstanding achievement gap, but people living in low-income neighborhoods often have minimal access to safe, green outdoor spaces which have been demonstrated to deliver benefits to human health; such spaces can boost cardiovascular health, mental health, and self-reported general health. The mechanism underlying such health benefits is complex, but it could be attributed to the ecological and social functions of green spaces. Improved physical health may be achieved through different pathways

such as mitigating exposure to heat and air pollution, alleviating stress, and encouraging more physical activity. There is mounting evidence that green space is associated with lowered cardiovascular risk and decreased mortality due to cardiovascular diseases (Plans et al. 2019; Shen and Lung 2016; Seo et al. 2019). Moreover, greener environments can impact aspects of brain function including cognitive development, stress recovery, attention restoration, and improved general emotional well-being. Recent studies have demonstrated that greenery in urban settings increased people's perceptions of happiness, lowered mental distress, and is positively associated with life satisfaction (Navarrete-Hernandez and Laffan 2019; Krekel et al. 2016; White et al. 2013). If designed with equitable access and distribution in mind, urban green spaces can be a powerful tool to deliver a wide range of benefits for disadvantaged communities, who are otherwise unable to reap the full health and environmental benefits of green space.

To foster the next generation of scholars, urban youth should be offered feasible solutions to inequity. A growing body of literature suggests that greening interventions in and around schoolyards may improve youth health and in turn, boost academic achievement. "Green schoolyards" are defined as spaces that incorporate natural elements (e.g., gardens, green spaces, trails, trees) with play features and/or outdoor learning components (Bohnert et al. 2021). Experimental studies echo the interest in understanding the restorative benefits of green schoolyards on underlying factors required for success in school, including attentional capacity and reduced stress levels. Views of greenery from classroom windows improved attentional functioning and recovery from stress, whereas a no-window or barren window view did not (Li and Sullivan 2016). Study breaks from classroom work in larger green spaces restored cognitive performance in adolescents and students also reported feeling more relaxed (Wallner et al. 2018). Levels of physical activity are also greater in outdoor green spaces, as MVPA (Moderate to vigorous physical activity) was five times greater among children who spent more than 20 minutes in green space compared to children with no green space exposure (Almanza et al. 2012). Ultimately, the benefits of green space on student well-being and academic performance are well-established.

While many studies focus on the link between green spaces and students' physical or mental health (Li and Sullivan 2016; Holt et al. 2019; Akpinar 2016), there is limited research that focuses on direct academic outcomes including standardized test scores, end-of-semester grades, and college preparatory exams. A number of confounding factors may influence student

performance, such as socioeconomic factors, gender, abilities, school district, race/ethnicity, class size, etc. (Markevych et al. 2019). Although the mechanistic pathways involved in the academic benefits of green space are still unclear (Browning and Rigolon 2019), the environmental and social benefits are well-documented in literature. There is more research underway regarding how widespread the impacts of nature are, which features of green space are most impactful, and at what spatial scale (Tallis et al. 2018). Prior studies in the United States have taken place on the East Coast or Midwest including Massachusetts, Minnesota, Michigan, and Chicago (Wu et al. 2014; Hodson and Sander 2017; Matsuoka 2010; Browning et al. 2018). Yet, no research has examined the effects of green surroundings on academic performance in the San Francisco Bay Area.

In this study, I ask: Is there a correlation between school greenness and test scores in the San Francisco Bay Area? By estimating green space coverage, examining student academic outcomes, and collecting socio-demographic secondary data, my current study also aims to ask (1) What is the relationship between socioeconomic factors and test scores? (2) How does green space vary with socioeconomic and demographic factors? (3) How do quantity, design, and type of green space relate to academic achievement? I predict that green space will have a dose-response effect on academic performance; greater levels of green space and improved accessibility to students will elevate test scores through direct and indirect psychological pathways. Moreover, I expect school tree coverage and greenness to vary with socioeconomic factors, which will be inferred by the measure of "disadvantage" among students. Ultimately, wealthier school districts will not only experience increased school greenness but also greater neighborhood greenness.

BACKGROUND AND FRAMEWORK

Study site description

This study examines public elementary schools in California. In 2022-2023, California had a total of 1,018 school districts, of which 517 districts contained elementary schools. Enrollment in elementary schools reached 2,748,015 across 5872 individual schools. Hispanic or Latino students comprise 55.9% of total enrollment. White students make up 21.1% of the elementary school population, followed by Asian students (9.5%) and African American students (5.1%) ("EdData - State Profile - California Public Schools" n.d.). The average class size for teachers in self-contained classes is 24.2 students, which is higher than the national average of 20.9 students per class ("National Teacher and Principal Survey (NTPS)" n.d.). Although curriculum requirements will vary based on individual school districts, elementary curriculum generally encompasses basic arithmetic and algebra in mathematics, fundamentals in English proficiency, and other subjects. Most school districts assign schools based on a student's residence address, while some school districts permit inter- and intra-district transfers, allowing students to attend a school other than the designated school within or outside their district. Overall, public schools are integral to the students who attend those schools and the surrounding community. Public schools function as community hubs; 1 in 5 Californians visit public schools each year, whether to attend school, to pick up or drop off a child, or to engage with other services.

There is a burgeoning interest in elementary school students as a study group in education research and policymaking. Early childhood experiences are important because they can shape later-life outcomes including high school and higher education outcomes, income, SES, health insurance coverage, crime, and substance abuse (Daines et al. 2021). Typically, elementary schools in California include kindergarten to 5th grade or in certain schools up to 6th grade, and the students are between the ages of 5-11. Unlike adults, young children are unique because they experience formative growth through interactions with their surroundings, social opportunities, and play.

Natural environments, in particular, provide opportunities for complex and creative types of play that cannot be accomplished in conventional playground settings. The fascination that

children have towards the natural world instills in them a lifelong sense of care and responsibility for nature (Wilson, 2007). When incorporated into their learning environment, natural elements can have a profound impact on the children's academic performance. Studies have demonstrated a strong, positive link between greater amounts of vegetated spaces on campuses and higher academic performance (Matsuoka, 2010; Wu et. al, 2014). Disruptions to society caused by climate change, COVID-19, and rapid urbanization have widened the achievement gap among students, historically marginalized and low-income populations experienced even greater barriers to success while learning remotely (Bailey et al. 2021). Ultimately, investing in youth health, well-being, and educational outcomes can help promote equity and resilience for future generations.

Factors affecting academic achievement: SES

A number of intrinsic and extrinsic factors can determine academic success at the elementary level, including family socioeconomic status, gender, interest in learning, and intelligence (Considine and Zappalà 2002). Socioeconomic status (SES), is a measure of one's overall social status in society considering education, employment status, and income. The influence of SES is quite substantial. As demonstrated in one longitudinal study, it was found to account for approximately 20% of the variance in childhood IQ (Gottfried et al. 2006). Multiple other studies cite that students from low-SES backgrounds are more at-risk of not graduating high school and performing more poorly in school due to limited access to materials and resources (Sirin, 2005). Education researchers and policymakers often use free and reduced-price lunch (FRPL) status to determine socioeconomic disadvantage (Domina et al. 2018). 1 in 5 children in the United States live in food-insecure households, and initiatives like The National School Lunch Program (NSLP) provides free or reduced-price meals to low-income children ("National School Lunch Program (NSLP) | Feeding America" n.d.). Children in households with incomes below 130 percent of the poverty level or those receiving SNAP (Supplemental Nutrition Assistance Program) or TANF (Temporary Assistance for Needy Families) qualify for free meals. On the other hand, those with family incomes between 130 and 185 percent of the poverty line qualify for reduced-price meals. In 2021-2022, 3,404,572 students attending public schools in California were eligible for NSLP ("EdData - State Profile - California Public

Schools" n.d.). In this study, eligibility for free and reduced-price meals will be used as a proxy for SES.

Research framework

The restorative mental and psychological benefits of green spaces are well-documented in literature; such benefits can lead to better educational outcomes through stress reduction and improvements to cognitive well-being. Previous studies have referred to two theories in explaining the effects of nature on cognition and well-being: Attention Restoration Theory (ART) and Stress Recovery Theory (SRT).

Attention Restoration Theory (ART)

ART of Kaplan and Kaplan (1989) proposes that mental fatigue is caused by focusing on a specific stimulus or task voluntarily and the condition can be improved by spending time in or looking at nature (Chawla et al. 2014). Restorative natural environments embody the following four characteristics; they: (1) Allow individuals to dissociate from normal attentional demands (i.e "be away from it all"), (2) Encourage thoughtful reflection, (3) Are an environment that is compatible with an individual's intrinsic motivations and (4) Mediate exposure to stimuli that is "softly fascinating" (Kaplan, 1995). Within the context of school environments, students are often subjected to continuous mental tasks which leads to what Kaplan terms "direct attention fatigue" (1995). Students who are mentally exhausted may display irritable behaviors, be distraught, or have trouble concentrating or performing simple tasks. Such outcomes pose a detriment to academic performance. Several studies have shown that spending time or even having access to views of a green landscape can improve both direct attention and performance. Wallner et al. (2018) found that study breaks in green spaces are effective in improving the cognitive performance of adolescents, and Li and Sullivan (2016) arrived at a similar conclusion when high school students with classroom window views of green landscapes recovered from stress much faster. Even small yet concentrated "doses of nature" have a positive impact. For instance, children with attention deficits concentrate better after walking in a park (Taylor and

Kuo, 2009). These findings provide support for the idea that natural environments can indirectly boost academic performance by enhancing focus and expediting recovery from mental fatigue.

Stress Recovery Theory (SRT)

SRT of Ulrich et al. (1991) posits that humans are hardwired through evolution to respond positively to safe natural settings such as trees, vegetation, and water. Thus, nature brings about a sense of restoration through automatic physiological reactions that provide rapid recovery from stress. Within demanding contexts like workplaces, views of nature have been proven to reduce stress and increase worker satisfaction (Shin, 2006). Recent studies have used cortisol concentration as a biomarker of stress, however, little research has been done on the impact of contact with natural environments on the neuroendocrine system. Roe et al. (2013) attempted to address this informational gap by testing whether the availability of neighborhood green space is linked to lower stress through diurnal salivary cortisol levels. The study found that the cortisol slope was negatively associated with perceived stress and positively associated with more green space. Ward Thompson et al (2012) also employed cortisol sampling and found a positive correlation between the diurnal decline in cortisol in a day and the percentage of green space. While exposure to nature may reduce perceived stress levels, this may not be reflected by the stress levels as measured chemically (Tyrvainen et al, 2014). Therefore, the relationship between nature and stress recovery is complex and also mediated by other factors such as the restorative qualities of nature, maintaining social connections, and increased outdoor recreation (Hodson and Sander, 2017).

Green space and youth populations

Some studies show that the link between green space and child or adolescent outcomes is rather complex as that link is moderated by external factors, such as sex, SES, and ethnicity (Mueller and Flouri 2021). Thus, most theoretical and empirical work on green space and mental health has been done with adults but there is a growing interest in investigating youth group outcomes. Studies on young people have produced results that parallel studies with adults. The presence of nearby nature in rural settings can buffer the impact of life stress on children; a

greater buffering effect was observed in those with exposure to greater life stress. The children experiencing more nature also reported a higher sense of self-worth and reduced psychological distress (Wells and Evans, 2003). Relocating to a greener dwelling environment was correlated with improved cognitive functioning of children aged 7-12 (Wells, 2000). Several studies have been conducted in schools. One study found that after spending time in an outdoor education setting in the forest compared to a conventional indoor school setting, adolescents reported a greater sense of energy, happiness, and less stress (Roe and Aspinall, 2011). Preschool children playing in large and integrated outdoor areas containing large areas of trees, shrubbery, and hills had lower levels of forgetfulness and hyperactivity (Martensson et al., 2009). To summarize, the Attention Restoration Theory is based on cognitive processes while the Stress Recovery Theory focuses on emotionally based mechanisms. Integrating both theories can help create a more comprehensive theoretical framework for mental restoration when studying the restorative effects of nature on children.

Despite the limited number of studies that directly examine the academic benefits of greenery, two recent studies focused on elementary school students have suggested that greater amounts of vegetated spaces on campuses can lead to better academic performance (Wu et al., 2014, Kuo et al., 2018). Wu et al's (2014) study was conducted in the areas surrounding 905 public elementary schools in Massachusetts. The researchers used the composite school-based performance scores to measure the percentage of third graders that scored "Above Proficient" (AP) in English and Math tests. Surrounding school greenness was determined using Normal Difference Vegetation Index (NDVI) data from March to October. Overall, the study found that students with higher exposure to green space performed better academically compared to students with lower exposure. Comparably, Kuo et al. (2018) is a cross-sectional study that examined 395 public elementary schools in Chicago, where academic underachievement is of pressing concern in the Chicago Public Schools district. Greenness was assessed for each school for two kinds of green cover (tree canopy cover and grass/shrub cover) and three geographic zones (catchment, school, and neighborhood). Achievement was determined as the percentage of third graders meeting or exceeding expectations in reading and math on the ISAT (Illinois State Board of Education's Illinois Standardized Assessment Test). The study found that the interaction between greenness and academic achievement is different for student bodies with different levels of disadvantage. The most disadvantaged groups may be more responsive to a

greener school environment. However, disadvantaged schools may lack a large enough "dose" of green to make a difference in achievement.

Limitations of prior research

One limitation of Wu et al's (2014) study was that the NDVI measures do not distinguish between different types of green (tree, grass, and shrub), even though not all types of landscapes have the same beneficial properties. For instance, studies have suggested that tree canopy contributes most to positive academic achievement whereas grass/shrub cover could have a negative effect on academic performance (Kuo et al., 2021, Kweon et al., 2017). Another consideration worth noting is the distribution of green space among schools relative to racial and income composition, which were not accounted for in Wu et al's study (2014). Evidence points to lower-income and minority residents experiencing a lower availability of green space (Schule et al., 2017). One study found fewer street trees in neighborhoods containing a higher proportion of African-Americans, low-income residents, and renters (Landry and Chakraborty, 2009). As the schools that I have chosen for my study are neighborhood-based, the racial and income composition of the schools is more likely to reflect the residential communities they lie within.

Methodology

In light of the limitations of prior studies, this current study aims to circumvent them by analyzing multiple classes of greenness: school grass cover, school tree canopy, and neighborhood tree canopy. Urban tree canopy assessments on iTree were used to distinguish between vegetation types. Next, I evaluated each type of green against test scores to expound the nuances of green space benefits. Race and SES are two confounding factors that I have addressed throughout the study. I combined my proxy for SES, % of students eligible for free and reduced-price meals, with % of students who identify as non-White and non-Asian into a single averaged variable to represent "disadvantage". Given the fact that poverty and minority status are correlated and both key predictors of achievement, combining them into a summary index is a statistically robust way to prevent multicollinearity (Kuo et al., 2018).

METHODS

Data collection

I chose four San Francisco East Bay school districts to examine their students' test scores. The East Bay is the most populous and geographically diverse subregion in the Bay Area, with a population of approximately 2.8 million in 2022 ("East Bay EDA" n.d.). My chosen districts include Berkeley Unified School District, Fremont Unified School District, Hayward Unified School District, and Alameda Unified School District. These districts were chosen because the schools are assigned based on a student's residence address. Hence, the student population is more likely to reflect the demographics of the broader community. Complete enrollment data was available online from the "California Department of Education" site for all schools. As the central focus of my thesis is to investigate public elementary schools only, I excluded four magnet schools and four charter schools. Some schools were situated near other public green spaces, but only green spaces less than 800 ft away from the main school buildings and not separated by a major highway were considered as part of the green space analysis. Other public spaces including groves, lakes, mini-parks, and playgrounds were excluded from the analysis because they did not capture the types of green space I was interested in (i.e. trees, shrubs, and grass). The final sample size was 36 schools.

Analysis

Statistical correlations

I conducted statistical analyses to determine how much variation in elementary student performance was explained by socioeconomic factors commonly known to influence student achievement. The research files containing demographic and socio-economic school data were obtained from the "California Department of Education" website. The test scores were taken from the California Assessment of Student Performance and Progress (CAASPP) website. In all the analyses, I used the Smarter Balanced Summative Assessments English Language Arts (ELA) and Mathematics test results from 2022. For each school, the individual ELA and

Mathematics scores were combined into a single mean scale score for student achievement, the scores fall on a continuous numerical scale ranging from approximately 2000 to 3000 varying by grade.

To understand student body SES, the percentage of students eligible for free and reduced-price lunch was collected. The evidence for a race gap in test scores is well-documented in literature. Because students from historically under-represented races and immigrants for whom English is not a first language show poorer performance in earlier education (Shapiro and Purpel), I decided to include percent of students who identify as non-White and non-Asian, and percent of English learners. The original descriptors in the ethnicity dataset were African American, American Indian or Alaska Native, Asian, Filipino, Hispanic or Latino, Pacific Islander, White, two or more races, and not reported. In this study, I inferred SES from the % of students eligible for free and reduced-price lunch and minority representation as the % of students who identify as non-White and non-Asian. As SES and minority representation are highly correlated ($r = 0.91$, $p < 0.001$) and both are important predictors of academic performance, I have combined them into a single variable: Disadvantage. School-based factors such as the number of students enrolled, pupil/teacher ratio, and % of female students were also considered. The number of students is considered a potential predictor of academic achievement since the total number of students may influence pupil-teacher ratios and consequently, the attention and resources given to each student. Moreover, gender may be another relevant factor because prior studies have demonstrated that girls generally outperform boys in a majority of subjects, the observed gender differences were attributed to biological and genetic factors, variations in abilities, the type and level of motivation, differences in learning style, etc (Burusic et al.).

Firstly, bivariate correlations were used to understand which socioeconomic factors had a direct impact on academic achievement. Confounding factors that were irrelevant to achievement were excluded from subsequent analyses. After obtaining the green space coverage for each school (see "Analysis 2: iTree" below), I evaluated socioeconomic factors against the quantity of green space found in each school site. Lastly, to address the primary aim of my study, I conducted bivariate correlations between green space coverage and test scores. I used a threshold probability of "$p \leq 0.05$" to determine statistical significance. The software Rstudio was used to conduct all my statistical analyses (R Core Team 2022).

iTree

To estimate the amount of green cover available at each school site, I used iTree Canopy to survey aerial imagery and identified areas with trees, grass, and impervious surface cover. I opened the iTree canopy software, entered the address of each school, and drew a boundary around the outer edge of the campus (stopping at the innermost edge of the sidewalk). Next, i-Tree Canopy randomly generates sample points and zooms to each one so you can choose from your pre-defined list of cover types for that spot. I aimed to get around 300-500 points for each site to ensure the accuracy of the cover estimates.

My list of cover types were school tree/shrubs, school grass/herbaceous, impervious road, impervious buildings, impervious asphalt playground, and soil/bare earth. For school sites near parks, I included a separate category for park trees/shrubs and park grass/herbaceous. I followed the same steps as above for all 36 schools. Based on the sample points entered into iTree, the software generates % Cover and Area (ft^2) statistics for each cover class. For the purpose of this study, I will only be considering the % Cover since the campus size of each school varies.

Interviews

To understand how students perceive and interact with green space, I administered structured interviews to relevant stakeholders including parents from the PTA committee, school teachers, principals, etc. The questions were formulated to investigate the challenges of creating and maintaining green space in schools, and key stakeholders' perceptions of the benefits for students. A final open-ended question was asked to stimulate the discussion or to gain more insight into what was not mentioned earlier in the interview.

Table 1. Interview questions organized by theme and stakeholder.

Theme	Questions	Stakeholder
Student's interaction with and perception of green space	1. What activities do children in schools use the greenspace for? 2. How much time do children spend in green space? 3. How frequently do the students use the green space? 4. Generally speaking, how do students feel about green space? (happy, relaxed, neutral, etc.) 5. Does the green space serve to add educational value to students? (eg: school gardens) 6. What benefits have you seen from students as a result of the garden/green space? 7. How has COVID-19 impacted the use of green space?	Principals, teachers, garden instructors, non-profit founder
Maintenance and Funding	1. Would you describe the space as well-maintained? 2. How large is the green space/garden? 3. How much funding is required to maintain existing green spaces? 4. Where does the funding come from? 5. How is the budget for green spaces on campus allocated? 6. Who is responsible for maintaining the gardens/green spaces? (staff, volunteers, students, etc.)	PTA members, principals
Policy	1. How can green space access/quality be improved through policy changes? 2. What are the environmental benefits of green schoolyards? 3. How does that support climate adaptation policies? 4. How can policy changes be used to encourage more schools to implement green spaces? 5. What other sources of support (apart from policy) might help to encourage more green space/gardens? 6. What do you think is the greatest barrier to implementing green spaces in schools? 7. What are the gaps in knowledge in green schoolyard research?	Environmental economist, non-profit founder
Gardening	1. Which grades use the garden? 2. How many raised beds does the garden have? 3. Have there been times when the garden has been used more often or less? 4. Does the garden serve to add educational value to students? If so, who leads the	Principals, teachers, garden instructors

		program/garden curriculum?	
	5.	Have you noticed that the garden is able to increase students' interest in certain subjects?	
	6.	What happens to the garden space over the summer?	
	7.	Is the garden only open to students or to the community?	
Ending	1.	Is there anything you want to add about green space?	All

After making transcriptions of the interviews either by hand, through Zoom's auto-transcription feature, or using Otter.ai, I created a codebook displaying the common codes that emerged throughout the interviews and descriptions of each. I initially developed primary codes based on the kinds of questions I prompted in the interview. After reviewing the transcriptions of the interviews on Taguette, I revised existing codes or added more to capture novel themes that arose. I grouped relevant codes under broader themes to capture six main ideas that I wanted to explore in greater detail.

RESULTS

Results of statistical correlations and iTree (1 & 2)

As expected, *Disadvantage* was strongly correlated with test scores ($r = -0.94$, $p < 0.001$); suggesting that racial and economic inequities play a role in determining academic outcomes. Similarly, both *% of students eligible for free and reduced-price lunch* ($r = -0.9355769$, $p < 0.001$) and % Minority representation ($r = -0.9103668$, $p < 0.001$) displayed a significant negative relationship to test scores. *% of English learners* was also significantly correlated with test scores ($r = -0.6847906$, $p < 0.001$). Overall, the Pearson correlation coefficients were of a magnitude that suggested a fairly meaningful relationship between the primary factors determining *Disadvantage*. On the other hand, the *Number of students enrolled* ($r = 0.2406413$, $p = 0.1574$) and *% of female students* ($r = -0.2228622$, $p = 0.1914$) were only moderately related to test scores. Similarly, *Pupil-teacher ratio* ($r = 0.07892647$, $p = 0.6473$) showed a weak correlation to test scores. Hence, none of the school-based variables were examined further in subsequent analyses. As a result, I only considered *Disadvantage* in my future analyses.

Table 2. Descriptive statistics of school-related, SES, and green variables.

Variables	Range	Mean ± SD
Mean scale score for English Language Arts (ELA) and Mathematics	2382 — 2594	2495.36 ± 55.40
Number of students enrolled	236 — 1082	507.47 ± 195.14
Pupil/teacher ratio	11.80 — 22.70	18.14 ± 3.24
% of female students	44.68 — 53.88	48.83 ± 2.18
% of students eligible for free and reduced-price lunch	7.50 — 65	29.42 ± 16.96
% Minority representation	10.20 — 95.40	51 ± 25.38
% of English learners	5 — 63.10	19.89 ± 14.09
% Disadvantage	9.60 — 78.75	40.21 ± 20.72
% School grass/herbaceous cover	0.3 — 56.83	17.83 ± 14.90
% School tree/shrub cover	0.66 — 34.99	9.40 ± 8.42
% Park grass/herbaceous cover	1.91 — 42.29	23.56 ± 13.25
% Park tree/shrub cover	0.6 — 11.86	6.13 ± 3.26

To address the primary aim of the study, I conducted bivariate correlations between greenness variables and test scores. Green space coverage was broken down into four specific classifications: School tree/shrub, school grass/herbaceous, park tree/shrub, and park grass/herbaceous. Of the 36 schools I surveyed, 13 were situated within 800 ft of a nearby park. The park green space was included as a part of the greenness analysis but denoted as a separate cover class. I found that school trees and park grass were moderately correlated to test scores ($r = 0.30$, $p = 0.078$, and $r = 0.41$, $p = 0.161$ respectively), indicating that they are drivers of academic performance. Neither park trees nor school grass was related to reading or math performance, hence I did not examine them further.

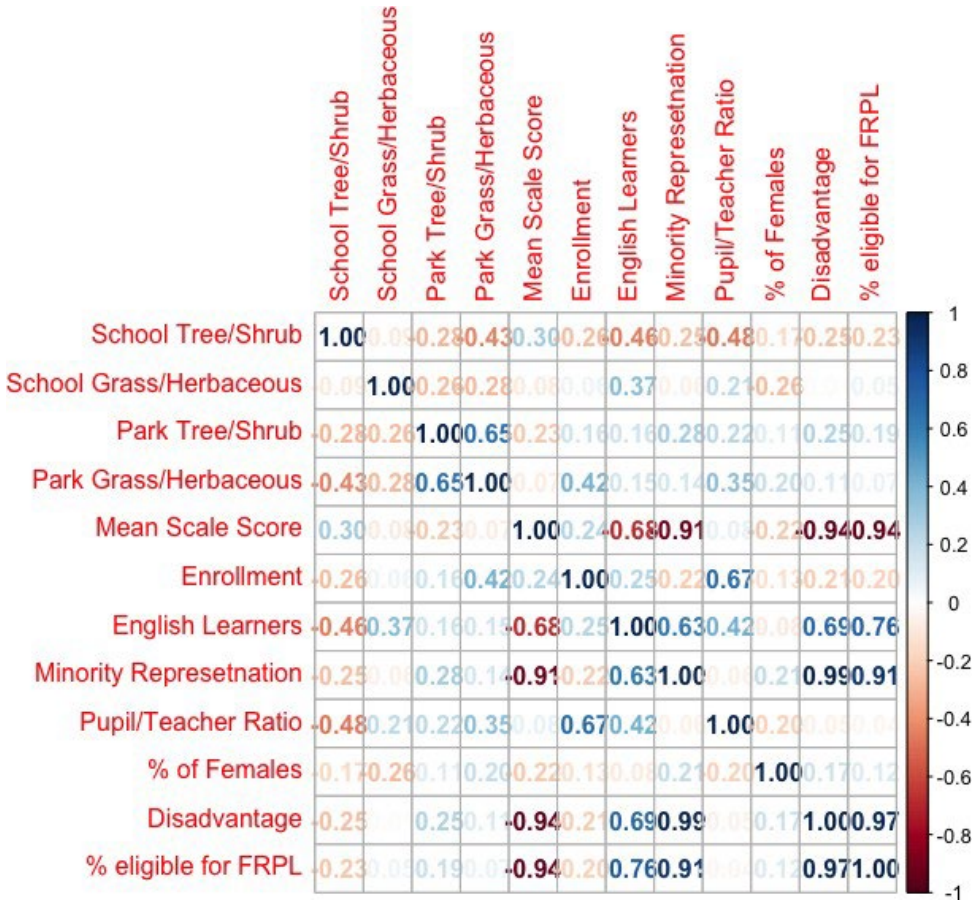

Figure 1. Correlation coefficient matrix. The school-based, SES, and green variables I chose were visualized using R (R Core Team 2022).

As the racial and income composition of schools are typically tied to the residential communities they lie within, it is important to assess the relationship between green cover and socioeconomic variables. The bivariate correlations revealed that disadvantage was moderately negatively correlated with school trees (-0.25, p = 0.1411) but was not related to school grass. Disadvantage was also not related to park grass but surprisingly, showed a moderately significant positive correlation to park trees (0.25, p = 0.1408). Based on my results, it can be deduced that schools serving more disadvantaged students were systematically less green for certain types of green space; suggesting that SES factors not only impact achievement but also the levels of greenness students are exposed to.

Results of Analysis 3: Interviews

I contacted all schools within my study sample with a school garden or a significant amount of green space on campus by email to participate. I reached out to the principals of each school and any relevant staff responsible for managing the green space (garden educator or science teacher). A total of five schools agreed to participate (response rate (RR): 50%), but two of the schools did not respond after my follow-up emails to schedule an interview. In the end, only three schools were interviewed.

The main reasons to decline were lack of time and the garden falling into disuse. I also contacted other stakeholders who were involved with green schoolyards (environmental economist, non-profit founder, PTA committee member). In total, 6 people were interviewed: one principal, one science teacher, one non-profit founder, one environmental economist, one PTA member, and one garden educator.

Based on the codes I derived from the interviews (Table 3), I synthesized them into six overarching themes (Table 4). The themes were: barriers to green space, schoolyard design, interactions with green space, perceived effects on students, policy, and learning.

Table 3. Codebook of relevant codes and the number of highlights for each.

Codes	Description	No. of highlights
Access to green space	How easily students can utilize, view or reach the green space	10
Barriers to green space	Challenges related to green space such as staffing, space, funding, lack of time, etc.	10
COVID-19 Pandemic	Global outbreak of coronavirus, an infectious disease caused by the severe acute respiratory syndrome coronavirus 2	7
Challenges with non-members	Outsiders to the school that create issues relating to safety and security	2
Climate Mitigation	Efforts to reduce the emission of greenhouse gasses and the secondary effects of global warming (extreme heat, flooding, drought, etc.)	6
Community support	How community volunteers and parents can help maintain and beautify the green facilities	6
Conflict among students	Misunderstandings, fights, bullying, and rivalry among student groups	6
Edible garden	Growing produce that is safe to consume	3
Emotional benefits	Green space strongly protects against mood disorders, depression, and stress-related issues	3
Frequency of green space usage	How often do students interact with the green space	3
Funding	Financial support provided to maintain green spaces	13
Goal of green space	Why was the green space implemented	3
Hands-on Learning	Instructors engage with students in direct experience and reflection to enhance students' knowledge, skills, and values.	10
Maintenance	Funding, staffing, and time required to ensure that the spaces are well-kept and safe for users	12
Outdoor Learning	Organized learning that takes place in outdoor spaces	7
Play	Activities that children engage in for recreation and enjoyment, it is the means by which children explore and experience the world	6
Policy	Actions adopted by the government or local district to encourage more greening on campus	6
Recreating Nature	Creating natural ecosystems and landscapes in places where it has been disturbed	4
School Curriculum	The lessons and academic content taught in a school	6
Schoolyard Design	Deliberate choices on what natural elements to include and where to place them to maximize benefits	11
Variability	A diversity of different play structures and nature-based elements	6

Table 4. Quotes from interviewees organized by theme.

Themes	Codes	Quotes
Barriers to green space	Maintenance	Economist: "The barriers tend to be perceived costs of maintenance." Principal: "In a less funded district or a district that didn't feel like this was important, you could say that [green space] is too much of a hassle, we don't want to deal with it so that's just off limits."
	Challenges with non-members	Parent: "We've unfortunately had some problems with vandalism. Our fence is quite easy to scale." Garden educator: "It's fenced-in and connected to their play areas…..but people can jump the fence, and it has been a target of vandalism."
	Staffing concerns	Non-profit founder: "School districts have 10% of the staff that they normally had 50 years ago to take care of grounds. Once we talked to one school district where they had one per school, I think it was 40 or 50 years ago, and now they have one per 11 schools."
	COVID-19 Pandemic	Teacher: "We could have more parent involvement if the pandemic slowed that way but it pushed stuff back." Garden educator: "A lot of the public schools here lost their garden educators during the pandemic, either they just couldn't get it together or the teachers quit."
Schoolyard design	Variability	Non-profit founder: "I think of a green schoolyard, which is more like a park at a school, a comprehensive green space with many, many different varied elements."
	Recreating nature	Non-profit founder: "Part of what we're trying to do in a green schoolyard is bring back the natural world on the natural world's terms."
	Maintenance	Economist: "The interest right now is focused on trees, because small forests can provide a lot of benefits and they're very low maintenance so if you have clusters of forests and create nature-based play around them, that's not actually a very expensive thing to do."
Interactions with green space	Access	Teacher: "[School garden] is open to everybody and I think everybody has used it from time to time."
	Frequency of use	Principal: "The kids are in the green space every day, I would say for about an hour." Garden educator: "All the classes come out every other week for about a real minimum of half an hour, 45 minutes on average, sometimes an hour if everybody's relaxed and fine."
	Play	Principal: "Our after-school program uses the spaces for exploration and play, and actually, the kids play here in the creek. They float boats and they do all kinds of fun stuff that you do when you have a creek." Parent: "Some kids don't have outdoor space at home. Some kids don't have things growing around them in their homes or near wherever they live. And so for some kids, [school is] maybe their only opportunity to play in the dirt, or get their hands dirty."

	Community support	Teacher: "We have a group of parents called the Green Team, and it's parents and teachers and we meet once a month and talk about all types of green initiatives for the school. They're very much a part of it."
Perceived effects on students	Conflict among students	Principal: "Kids' behavior has definitely been much better when they're outside" Non-profit founder: "Kids get into fewer fights if they're not bored. And so you have less bullying and you have happier children."
	Emotional benefits	Teacher: "I would definitely say that it reduces stress, especially for the kids in the garden club. I think it helps their self-confidence too, maybe, just because they use tools they might not use at home."
Policy	Climate mitigation	Economist: "I think that leaving the design of the school sites and the standards up to the individual districts when climate change is a global problem and needs statewide goals doesn't doesn't make any sense."
	Funding	Economist: "There's no reason every school district in California should be trying to figure [campus greening] out, the state should tell them what their goals are, and what the requirements should be and try to provide resources for districts that are low-funded."
Learning	Outdoor learning	Parent: "You know [students] get a break from sitting at a desk and doing work on a piece of paper, and they get to go outside and do things with their hands." Non-profit founder: "We need more climate curricula and environmental literacy curriculum to be taught outside."
	Hands-on learning	Teacher: "We do have a compost bin back there that we can spin, the kids love to turn the handle." Principal: "When you learn about a redwood tree in a book, it's really different than going out and touching a redwood when you learn about the plant cycle when you learn about photosynthesis when you learn about the seasons."
	School Curriculum	Garden educator: "There are so many subjects that gardening connects to. We could read a book and do a little history, you could do a little literature, we could do a little math, there's just a lot of little things that I'm hitting when I put together a lesson. It's really open-ended."

Barriers to green space

Of the four barriers presented, maintenance and staffing concerns were arguably the greatest challenges because they entail high perceived costs that may burden underfunded school districts. The COVID-19 pandemic further exacerbates these two barriers because of a lack of parent involvement and fewer qualified outdoor instructors. Meanwhile, vandalism and trespassing pose a security and safety concern for students and school members.

Maintenance

Maintenance was cited as a barrier to green space by several stakeholders. One interviewee explained in detail that school districts today only have 10% of the staff they had 50 years ago to take care of school grounds. They elaborated further about an instance where in one school district 40 or 50 years ago, each school had a designated groundskeeper. Now, they have one per 11 schools. Green spaces, unlike asphalt, require maintenance which can be costly for underfunded school districts; these districts may view green space as a hassle and choose not to implement it.

Challenges with non-members

Vandalism and trespassing are common issues that school gardens experience. Although the gardens are fully fenced-in, the fences can be easy to scale and people can access them without the school's permission. Garden access at most schools is restricted to students and teachers only because non-members would have to enter the school premises during school hours, which could be an obstruction to classes or recess.

Staffing concerns

There are two types of staffing concerns: one related to teachers and one related to maintenance staff. Teachers receive little training on how to teach outdoors and tailor their curriculum around natural spaces. In response to a lack of maintenance staff, a solution was

proposed: involving parent volunteers in the maintenance of the green spaces.

COVID-19 pandemic

The COVID-19 pandemic was perceived as a barrier since it limited parent involvement, triggered a high turnover for teachers, and created uncertainty for post-pandemic utilization. In one school, a science teacher resigned during the pandemic and it took some time for the school to hire a new teacher. Another interviewee noted that many public schools lost their garden educators during the pandemic. On the other hand, the pandemic increased green space usage in some schools. The main reason was that outdoor learning was encouraged to reduce virus transmission.

Schoolyard design

When designing a schoolyard, variability and recreating nature are intertwined. Emulating the diversity of elements found in nature is key to promoting different kinds of play and prosocial behavior among children. Thoughtful schoolyard design can also evade the barrier of maintenance since fully natural spaces contain "messes" that enhance nature's aesthetic. Prioritizing certain types of green space can also minimize costs and maintenance.

Variability

Variability is a key component in creating a schoolyard that is dynamic and comprehensive. Variability entails having different types of elements, similar to "niches" you would find in a natural habitat. Plain asphalt or a grass field only encourages a monoculture of activity geared towards ball sports. Outdoor spaces containing benches and seating are linearly arranged to serve the purpose of observation rather than social engagement. The interviewees emphasized that variability facilitates a wider diversity of activities. For instance, nature-based playgrounds consisting of hills, tunnels, and trees can benefit children by promoting different kinds of play and socialization while the trees reduce noise and provide shading. In regards to the goals of green space, variability in design is essential in addressing three purposes. An outdoor

classroom space can be used for seating during teaching time, it can also be a play area for recess, and depending on the design, could shade people or grow an edible vine on top.

Recreating nature

The interviewees gave examples of how recreating nature can occur in a schoolyard. One stakeholder noted that bringing back the natural world on the natural world's terms involves allowing processes such as plants going to seed and leaves falling to happen. Another stakeholder underscored the gardens are only a snapshot of what the land looked like before houses and farms were established. A school member recounted the interactions between animals observed on campus including seeing kingfishers prey on gophers and redtail hawks swooping down for squirrels.

Maintenance

Schoolyard design is tied closely to maintenance. A space that is designed to be fully natural is easier to maintain compared to a schoolyard with both natural and asphalt elements. What might be perceived as tripping hazards such as acorns, leaf litter, and tree branches can enhance nature's aesthetic and create opportunities for creative play if it occurs in a mulched area. Certain types of green spaces (i.e. gardens) are more maintenance-oriented and can be seen as a burden to staff members. The interviewees expressed that current greening efforts are focused on trees because they are low maintenance and cost-effective.

Interactions with green space

Interactions with green space can be either direct or indirect, and occur between students or parents. Student interaction with green space depends greatly on the ease of access and frequency of use. Access can be either physical or visual, however, physical access is essential for students to engage in play and exploration. Parents may interact with green spaces through volunteer opportunities or by funding the school district.

Access

When I asked about access to green space, the interviewees agreed that it was difficult for students to have unobstructed and unsupervised access to green spaces due to design flaws, rules enacted by the school, and physical barriers like fences. Both physical and visual access was mentioned. For example, some schools don't have many trees in the main schoolyard, but they had forested edges that the students were prohibited from accessing. An interviewee gave an example of a private school in Florida along the intercoastal area, where adults could enjoy the view out to the water from the schoolyard but the kindergarteners couldn't see over the four-foot fence. However, there are also instances where access can be enhanced by redesigning school infrastructure, whether that be natural or man-made. Another case described by an interviewee took place at Salmon Creek Elementary, a school in Occidental, California: "I think there are examples where there's one school in Occidental, it's called Salmon Creek Elementary that has a creek that runs through the property and they actually built a salmon viewing platform. It looks simple, but it was a large-scale project to get an engineered cantilever deck to go above the creek so the kids could watch the salmon returning up the creek and be in visual access to the water."

Frequency of use

The frequency with which students used green spaces varied greatly from school to school. At one school, students had access to garden spaces every day, while at another they used those spaces much less frequently, visiting for 45 minutes every other week. Overall, the frequency of usage could be higher at both schools. Outside of teaching, teachers utilize the garden or outdoor seating areas for their lunch breaks.

Play

Green space can provide opportunities for students to play and explore. In one school, kids participating in after-school programs can "float boats" in the creek and climb trees. There are several factors influencing play including the type of space available, the aesthetic of the play area, and the rules governing children's play. Ballgames and creative play for younger grades

tend to take place on asphalt and grassy areas. Creative play can be restrained by rules when teachers don't allow children to climb or stand on certain structures. Lastly, a space that is perceived as "messy" by adults (fallen leaves, mulch, sticks) can be beneficial for children by providing props for play and allowing them to submerge themselves in imaginative role-play scenarios.

Community support

Direct community support for school green spaces typically comes from parents and community volunteers. The amount of support varies across time and between schools; some schools experienced difficulties with setting up and low volunteerism since the COVID-19 pandemic. Another school had a more positive experience with parent involvement: their school has a parent-led group called the Green Team which meets once a month to discuss green initiatives at the school. Community support can help fund the school district. For example: In Berkeley, voters passed the "Berkeley School Excellence Project" which gives 30% more dollars per student to keep the school grounds green and beautiful.

Perceived effects on students

Green space can provide many emotional and behavioral benefits to students, including defusing conflict among students, reducing stress, and boosting self-confidence. Green space induces a calming effect on students while helping to combat boredom through new and stimulating experiences, thus students tend to be happier and less agitated.

Conflict among students

Green space can ease conflicts among students, improve their behavior, and combat boredom. As a result, children get into fewer fights, experience less bullying, and are happier. One interviewee points out that children's behavior is much better when they have lunch outside as opposed to in the cafeteria. Lunch in an enclosed space like a cafeteria is louder and more disruptive, which can give rise to more behavioral problems among students. Conflicts can be

better resolved while outdoors in nature. For example, one school runs restorative justice circles for children experiencing conflict by the creek.

Emotional benefits

There is a consensus that green space has positive emotional benefits for students. Gardening not only reduces stress but also helps to boost the student's self-confidence by giving them opportunities to use tools they might not use at home. Garden spaces can also serve as a refuge for students who feel lonely. An interviewee explained that there is one student who is loud during lunchtime, so the school decided to allow him and his instructional assistant to have lunch by the creek. The student is more well-behaved and enjoys being in nature.

Policy

Policies aimed towards schoolyard greening should align with climate mitigation goals; extreme heat due to climate change is not solely an environmental concern, but it affects the well-being and safety of young children. While there are currently several state-wide initiatives in place, future policies should provide sufficient resources to under-funded school districts and not be in conflict with other existing policies (eg: ADA requirements).

Climate mitigation

Some policies can be used to address both schoolyard greening and climate change concerns. As temperatures continue to warm, it is imperative to plant more trees now to have sufficient tree canopy to shade students from extreme heat in the future. The best way to get buy-in for green spaces in schools is to focus on the impact of heat on children; hence funding for green spaces should come out of climate funds since the root issue is maintaining safe places for children in the face of climate change.

Funding

Setting clear statewide goals and allocating resources to low-funded districts are two ways to encourage more school greening in California. One of the interviewees is the founder of the non-profit "Green Schoolyards America," the organization that worked alongside US Senator Heinrich to create the "Living Schoolyards Act", which was the first green schoolyard-related legislation introduced to the US Senate. Another statewide initiative that aims to increase tree canopy on public school grounds in California is a collaboration between the California Department of Education and the state's forestry department (CAL FIRE). Both pieces of legislation are the first of their kind.

In some cases, policies can discourage schools from implementing greening projects. For instance, when non-profit organizations redesign and renovate playgrounds, they are required to pay for additional bathrooms to meet ADA (The Americans with Disabilities Act) requirements. These ADA upgrades could be costly which prompts the organization/school to abandon the project altogether.

Learning

Based on the decreased risk of virus transmission in an open-air environment, green spaces can be venues for versatile outdoor classrooms and school programming. In particular, green spaces can support environmental education and science curriculums by providing hands-on learning opportunities. Thus, allowing students to learn beyond the constraints of their classroom. Grants should be updated to match the school curriculum to provide meaningful and engaging lessons.

Outdoor learning

Outdoor learning can be adapted to teach a variety of subjects in an engaging way and allows students to take a break from being in the classroom. Outdoor learning was first adopted by many schools as a COVID-19 mitigation strategy. Examples of successful outdoor learning also came up during the interviews. For instance, students could engage in a poetry class where they are inspired by the nature around them. Math lessons can take place outdoors by using a pathway made out of paving stones to show children how different shapes look. Moreover,

science lessons on climate, temperature measurement, and graphing can be easily taught in an outdoor setting. At another school, science teachers take children out by the creek to learn about the water cycle.

Hands-on learning

Hands-on learning, unlike outdoor learning, involves learning by doing rather than listening to the teacher. One interviewee provided a case study of a school in Berkeley where the science teacher employed hands-on learning to teach students about geology: "15 years ago, while my kids were in elementary school in Berkeley, the science teacher and I went to apply for a grant and then got funds to put in boulders in the schoolyard. And she was trying to teach lessons about igneous, metamorphic, and sedimentary rock. And in the science lab, they had little handheld rocks that she could teach with. What we decided to do was to make the seating areas out of rock by distributing the boulders around the schoolyard. And so the kids could gather with their friends and have little seating spots for recess or for other things…..they were made out of all the rocks she wanted to teach them so when she did that lesson, she could bring the class outside and they could put on their goggles and take a hammer to it and do hardness tests. Or they could look at the strata in the rock, and see sedimentary rock, which you can't really do with small samples in your lab." Other popular hands-on activities mentioned by interviewees included planting seeds and turning the compost bin.

School curriculum

Green space can help integrate environmental education into the curriculum and target learning areas across grade levels and subjects. For instance, climate curricula and environmental literacy can be supported by learning in green space. One interviewee mentioned learning about the impacts of colonization on the natural landscape by questioning what the land looked like before the Spanish arrival in the United States. It is important to update grants to match the school curriculum to provide meaningful and engaging lessons for students in green spaces. Although schools are one of the most well-used public spaces in any city, they are not sufficiently funded.

DISCUSSION

As urban California continues to grow in size and complexity, it is imperative to adopt cost-effective solutions to support youth from disadvantaged communities and enable them to overcome existing health and income disparities in the United States. From an educational policy and schoolyard-design perspective, my findings emphasize that green schoolyards can elevate test scores through a number of relevant mechanisms: providing a safe space to engage in physical activity, promoting prosocial behavior, relieving stress and anxiety and creating opportunities for hands-on learning. The results add to a growing evidence base that green schoolyards can offer long-lasting benefits for individuals and communities (Stevenson et al. 2020, Kuo et al. 2021, van den Bogerd et al. 2023).

As expected, I found a strong negative relationship between socioeconomic status and test scores, as an indicator of academic performance. In my study area, low socioeconomic status is linked to lower academic achievement and slower rates of academic progress as compared to high SES communities, which is consistent with previous studies (Mccoy 2005, Caro et al. 2009, Lacour and Tissington 2011). Hayward Unified had the greatest proportion of students who qualify for free and reduced lunches and the greatest percentage of students whose performance did not meet the state standard. School-level factors (e.g., teacher/pupil ratio) were also considered as a part of this study but were only weakly correlated with test scores. Ultimately, the results indicate that non-White, non-Asian, and low-income students tend to perform less favorably on standardized English and math tests.

One explanation for the relationship between SES and academic achievement put forth by many studies is the “social causation model”. Some empirical studies support the view that students from a low SES background may struggle to match the performance of their high SES counterparts due to a lack of access to educational materials, family economic stress, and unsafe living conditions (Conger and Conger 2002, Li et al. 2020). Hence, the social causation model attributes financial, social, and human capital to influencing children’s functioning and development. Consistent with the “social causation model”, Smith et al. (1998) also concluded that a higher parental income affords children with a stimulating and dynamic learning environment, which can have positive effects on cognitive outcomes. Another potential explanation suggests that low SES students are targeted by stereotypic reputations of lower

intellectual ability (Sidanius & Pratto 1999), known as "stereotype threat" (Steele et al. 2002). The view of people from low SES backgrounds as "ignorant and lazy" legitimizes a social hierarchy that designates high SES groups as more intelligent and low SES groups as less capable (Bullock 1995). During a high-stakes situation for an individual, such as a test or exam, the fear of sustaining a negative allegation may in fact impair performance. Within the context of my study, the self-perceptions of students were not accounted for so it is unclear as to whether "stereotype threat" is a driving force behind the correlation between SES and achievement.

The two theories proposed above pertain to an individual student's SES; however, my study considers the average SES of the student body at each school. The extent to which the academic achievement of students is influenced by the input resources and the social status of their peer population has gone relatively unexplored. An influential study by Coleman (1968) found that the academic achievement of both African American and White students in the United States was most influenced by the backgrounds of fellow students. Another study has identified shared beliefs, habits, and peer pressure as important mechanisms by which peer groups affect individual academic achievement regardless of a student's own SES level (Caldas and Bankston 1998). In my study, the results support the existing notion that individual and school-level SES are significant determinants of academic performance.

Following my second subquestion, I determined that disadvantage was moderately negatively related to school trees. Thus, the more disadvantaged the student body, the fewer trees are found on school grounds. Previous studies focusing on green spaces in larger landscapes around schools illuminate the tendency for wealthier, greener neighborhoods to have greener schools (Baró et al. 2021, Kuo et al. 2018). Unexpectedly in my study area, the disadvantage variable had a moderate positive correlation with park trees. Obsensibly, this finding contradicts previous research because generally, low-income and minority residents tend to have lower access to community green space (Abercrombie et al. 2008, Dahmann et al. 2010, Astell-Burt et al. 2014). One study found that street tree cover was lower in neighborhoods with high proportions of African-Americans, low-income residents, and renters (Kweon et al. 2017). However, Lin et al. (2015) demonstrated an unusual finding where tree cover in public parklands in urban Sydney was slightly higher in areas of greater disadvantage. They attributed this pattern to a greater reliance on public green infrastructure due to a lack of private residential tree cover.

It is important to note that not all communities might exhibit the same pattern, however, in this study, disadvantaged communities seem to have equivalent availability of park tree cover.

In examining the contributions of various types of green space, school green space had a greater effect on academic achievement compared to park green space in my study. In the 36 schools that I observed, tree cover was the most important predictor of academic performance, unlike grass cover. This echoes past findings (Hodson and Sander 2017, Li et al. 2020), contending that the link between green cover and achievement is driven by tree cover. A similar study that sampled elementary schools in California also identified a positive relationship between school-level academic performance and tree cover (Tallis et al. 2018). Beyond the schoolyard, research shows that urban public green spaces consisting only of grass can have a negative impact on people. One study theorized that trees act through different pathways toward better health compared to other vegetation types (Reid et al. 2017). For instance, trees are more likely than grass to provide shade or reduce noise pollution (Turner-Skoff and Cavender 2019). Additionally, a lack of urban trees is associated with increases in crime (Kondo et al. 2017).

Equally important, green space design determines how students perceive and interact with the space. Drawing from my qualitative findings, a hazard-free, well-maintained, and varied green space is most effective for students' learning and well-being. Traditionally, asphalt-covered or flat grassy areas are favored by schools due to easy maintenance and perceived safety. However, such spaces promote monocultures of activity (e.g., ball sports) and hinder students from reaping the full benefits of being in nature. There are several different pathways by which green space can support child development including play, learning, and positive behaviors.

Proponents of schoolyard greening point to evidence that hands-on learning in nature can improve academic achievement across the curriculum by enhancing the learning environment and providing unique experiences for youth (Smith and Motsenbocker 2005, O'Brien et al. 2011). Moreover, my study results highlight green space as a space for children to engage in unconstrained play and exploration, such as climbing trees and imaginative play. As a result, levels of physical activity tend to be higher in outdoor green spaces for both boys and girls (Wheeler et al. 2010, Almanza et al. 2012) Relatedly, the current study revealed improvements in social cohesion and classroom conflict mitigation as reported by community stakeholders. Similar conclusions highlighting the effectiveness of green space in promoting prosocial

behaviors were reached by past studies (Odgers et al. 2012, Raney et al. 2019, Bohnert et al. 2021).

My study also suggests that green space provides direct emotional benefits to students including reducing stress, boosting self-confidence, and easing feelings of loneliness. My results reflect aspects of the Attention Restoration Theory (ART) of Kaplan and Kaplan (1989), which argues that spending time in nature can alleviate mental fatigue because the act of being in nature requires no effort at all. Stakeholder observations are consistent with the qualities of "soft fascination", "emotional refuge" and "being away" that the Kaplans associate with settings that promote attention restoration. Natural areas containing visually-fascinating elements like vibrant native flowers, hills, tunnels, and wild animals (i.e., birds, butterflies, and squirrels), allow students to take a break from the school-induced stress and be immersed in a restorative experience. However, when the students engage in imaginative role-play scenarios, they are not doing it involuntarily hence ART might not fully encapsulate how students engage with green space. Arguably, this paper's results are more compatible with the Stress Recovery Theory (SRT) of Ulrich et al. (1991), which proposes that nature has a restorative effect because humans are hardwired to view natural spaces as safe and thus respond positively to them. Physiological levels of stress would decline in safe natural settings while bringing about feelings of well-being. Even though my study did not directly measure the cortisol levels of students before and after green space exposure, the community stakeholders reported that positive emotions and stress relief often accompanied spending time in green space.

The multimethod approach of qualitative and quantitative analysis provides salient contributions to the literature, however, future work is needed to overcome the limitations of the current study. Firstly, the findings cannot be generalized as my sample size is not large enough to capture possible outliers. More significantly, the geographical scope of my study is limited to the East Bay Area. Expanding my study population to schools within the greater SF Bay Area or even California could reveal greater trends. Previous green space research has been conducted in the Midwest and East Coast states (Minnesota, Michigan, and Massachusetts) which serve relatively fewer disadvantaged students: 35.8%, 50.5%, and 32.8% low-income students in 2019-2020, respectively ("Digest of Education Statistics, 2021" n.d.). Although California has a higher rate of students eligible for free/reduced-price lunch (59.4%), it could be worthwhile to see whether the green space and school performance relationship would still hold in school

districts in a state with a substantial proportion of low-income students. As this study was both correlational and cross-sectional, no conclusions can be drawn regarding whether school greenness does affect school achievement while accounting for changes to school demographics and landscape over time. Since my study only focuses on neighborhood-based public elementary schools, it is impossible to say whether the same relationship found here extends to magnet, charter, or private schools. As the types of schools in the United States become more diverse, it is important to assess the contributions of school and neighborhood green space for all schools. As I found that tree cover, unlike grass, was tied to academic performance, future experimental green efforts should focus on planting trees to not only reap immediate, short-term benefits (enhanced aesthetic beauty of the schoolyard), but consider long-term benefits including mitigating climate change, providing shade for students, reducing stormwater runoff and improving air quality.

The outcome of my study emphasizes the urgent need to set clearer and more goal-oriented policies at the level of the state and the school district. My results suggest that the costs of planting and maintenance are significant barriers to green space, hence new policies should encourage schools to conduct more greening while providing them with the funds to do so. In the Bay Area, there are non-profit organizations and community groups that support landscape transformations through grants and design recommendations, i.e., Green Schoolyards America, Education Outside, and The Trust for Public Land. The efforts of these organizations allow even financially strapped schools to enjoy the benefits of a green campus.

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REFERENCES

Abercrombie, L. C., J. F. Sallis, T. L. Conway, L. D. Frank, B. E. Saelens, and J. E. Chapman. 2008. Income and Racial Disparities in Access to Public Parks and Private Recreation Facilities. American Journal of Preventive Medicine 34:9–15.

Akpinar, A. 2016. How is high school greenness related to students' restoration and health? Urban Forestry & Urban Greening 16:1–8.

Almanza, E., M. Jerrett, G. Dunton, E. Seto, and M. A. Pentz. 2012. A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data. Health & Place 18:46–54.

Astell-Burt, T., X. Feng, S. Mavoa, H. M. Badland, and B. Giles-Corti. 2014. Do low-income neighbourhoods have the least green space? A cross-sectional study of Australia's most populous cities. BMC Public Health 14:292.

Bailey, D. H., G. J. Duncan, R. J. Murnane, and N. Au Yeung. 2021. Achievement Gaps in the Wake of COVID-19. Educational Researcher 50:266–275.

Baró, F., D. A. Camacho, C. Pérez Del Pulgar, M. Triguero-Mas, and I. Anguelovski. 2021. School greening: Right or privilege? Examining urban nature within and around primary schools through an equity lens. Landscape and Urban Planning 208:104019.

van den Bogerd, N., D. Hovinga, J. A. Hiemstra, and J. Maas. 2023. The Potential of Green Schoolyards for Healthy Child Development: A Conceptual Framework. Forests 14:660.

Bohnert, A. M., L. M. Nicholson, L. Mertz, C. R. Bates, and D. E. Gerstein. 2021. Green schoolyard renovations in low-income urban neighborhoods: Benefits to students, schools, and the surrounding community. American Journal of Community Psychology 69:463–473.

Browning, M. H. E. M., M. Kuo, S. Sachdeva, K. Lee, and L. Westphal. 2018. Greenness and school-wide test scores are not always positively associated – A replication of "linking student performance in Massachusetts elementary schools with the 'greenness' of school surroundings using remote sensing." Landscape and Urban Planning 178:69–72.

Browning, M. H. E. M., and A. Rigolon. 2019. School Green Space and Its Impact on Academic Performance: A Systematic Literature Review. International Journal of Environmental Research and Public Health 16:429.

Bullock, H. E. 1995. Class acts: Middle-class responses to the poor. Pages 118–159 The social psychology of interpersonal discrimination. The Guilford Press, New York, NY, US.

Burusic, J., T. Babarovic, and M. Serie. 2012. Differences in elementary school achievement between girls and boys: Does the teacher gender play a role? European Journal of Psychology of Education 27:523–538.

Caldas, S. J., and C. Bankston. 1998. The Inequality of Separation: Racial Composition of Schools and Academic Achievement. Educational Administration Quarterly 34:533–557.

Cano, R., and J. Hong. 2020, February 3. Mind the achievement gap: California's disparities in education, explained. CalMatters.

Caro, D. H., J. T. McDonald, and J. D. Willms. 2009. Socio-economic Status and Academic Achievement Trajectories from Childhood to Adolescence. Canadian Journal of Education / Revue canadienne de l'éducation 32:558–590.

Chawla, L., K. Keena, I. Pevec, and E. Stanley. 2014. Green schoolyards as havens from stress and resources for resilience in childhood and adolescence. Health & Place 28:1–13.

Coleman, J. S. 1968. Equality of educational opportunity. Integrated education 6:19–28.

Conger, R. D., and K. J. Conger. 2002. Resilience in Midwestern Families: Selected Findings from the First Decade of a Prospective, Longitudinal Study. Journal of Marriage and Family 64:361–373.

Considine, G., and G. Zappalà. 2002. The influence of social and economic disadvantage in the academic performance of school students in Australia. Journal of Sociology 38:129–148.

Dahmann, N., J. Wolch, P. Joassart-Marcelli, K. Reynolds, and M. Jerrett. 2010. The active city? Disparities in provision of urban public recreation resources. Health & Place 16:431–445.

Digest of Education Statistics, 2021. (n.d.). . National Center for Education Statistics. https://nces.ed.gov/programs/digest/d21/tables/dt21_204.10.asp.

Dobuzinskis, A. 2019, September 25. U.S. minority students concentrated in high-poverty schools: study. Reuters.

Domina, T., N. Pharris-Ciurej, A. M. Penner, E. K. Penner, Q. Brummet, S. R. Porter, and T. Sanabria. 2018. Is Free and Reduced-Price Lunch a Valid Measure of Educational Disadvantage? Educational Researcher 47:539–555.

East Bay EDA. (n.d.). . https://eastbayeda.org/our-region/.

EdData - State Profile - California Public Schools. (n.d.). . http://www.ed-data.org/state/CA.

Faber Taylor, A., and F. E. Kuo. 2009. Children With Attention Deficits Concentrate Better After Walk in the Park. Journal of Attention Disorders 12:402–409.

García, E., and E. Weiss. 2017. Education inequalities at the school starting gate: Gaps, trends, and strategies to address them. https://www.epi.org/publication/education-inequalities-at-the-school-starting-gate/.

Gottfried, A. W., A. E. Gottfried, and D. W. Guerin. 2006. The Fullerton Longitudinal Study: A Long-Term Investigation of Intellectual and Motivational Giftedness. Journal for the Education of the Gifted 29:430–450.

Hidden Cities: Unmasking and Overcoming Health Inequities in Urban Settings. 2010. . World Health Organization.

Hodson, C. B., and H. A. Sander. 2017. Green urban landscapes and school-level academic performance. Landscape and Urban Planning 160:16–27.

Holt, E. W., Q. K. Lombard, N. Best, S. Smiley-Smith, and J. E. Quinn. 2019. Active and Passive Use of Green Space, Health, and Well-Being amongst University Students. International Journal of Environmental Research and Public Health 16:424.

Jao, A. 2018, January 12. Segregation, school funding inequalities still punishing Black, Latino students. https://www.nbcnews.com/news/latino/segregation-school-funding-inequalities-still-punishing-black-latino-students-n837186.

Kaplan, R., and S. Kaplan. 1989. The experience of nature: A psychological perspective. Pages xii, 340. Cambridge University Press, New York, NY, US.

Kaplan, S. 1995. The restorative benefits of nature: Toward an integrative framework. Journal of Environmental Psychology 15:169–182.

Kondo, M. C., S. Han, G. H. Donovan, and J. M. MacDonald. 2017. The association between urban trees and crime: Evidence from the spread of the emerald ash borer in Cincinnati. Landscape and Urban Planning 157:193–199.

Krekel, C., J. Kolbe, and H. Wüstemann. 2016. The greener, the happier? The effect of urban land use on residential well-being. Ecological Economics 121:117–127.

Kuhfeld, M., J. Soland, K. Lewis, and E. Morton. 2022, March 3. The pandemic has had devastating impacts on learning. What will it take to help students catch up?

Kuo, M., M. H. E. M. Browning, S. Sachdeva, K. Lee, and L. Westphal. 2018. Might School Performance Grow on Trees? Examining the Link Between "Greenness" and Academic Achievement in Urban, High-Poverty Schools. Frontiers in Psychology 9.

Kuo, M., S. E. Klein, M. HEM Browning, and J. Zaplatosch. 2021. Greening for academic achievement: Prioritizing what to plant and where. Landscape and Urban Planning 206:103962.

Kweon, B.-S., C. D. Ellis, J. Lee, and K. Jacobs. 2017. The link between school environments and student academic performance. Urban Forestry & Urban Greening 23:35–43.

Lacour, M., and L. D. Tissington. 2011. The effects of poverty on academic achievement.

Landry, S. M., and J. Chakraborty. 2009. Street Trees and Equity: Evaluating the Spatial Distribution of an Urban Amenity. Environment and Planning A: Economy and Space 41:2651–2670.

Li, D., and W. C. Sullivan. 2016. Impact of views to school landscapes on recovery from stress and mental fatigue. Landscape and Urban Planning 148:149–158.

Li, S., Q. Xu, and R. Xia. 2020. Relationship Between SES and Academic Achievement of Junior High School Students in China: The Mediating Effect of Self-Concept. Frontiers in Psychology 10.

Lin, B., J. Meyers, and G. Barnett. 2015. Understanding the potential loss and inequities of green space distribution with urban densification. Urban Forestry & Urban Greening 14:952–958.

Markevych, I., X. Feng, T. Astell-Burt, M. Standl, D. Sugiri, T. Schikowski, S. Koletzko, G. Herberth, C.-P. Bauer, A. von Berg, D. Berdel, and J. Heinrich. 2019. Residential and school greenspace and academic performance: Evidence from the GINIplus and LISA longitudinal studies of German adolescents. Environmental Pollution 245:71–76.

Mårtensson, F., C. Boldemann, M. Söderström, M. Blennow, J.-E. Englund, and P. Grahn. 2009. Outdoor environmental assessment of attention promoting settings for preschool children. Health & Place 15:1149–1157.

Matsuoka, R. H. 2010. Student performance and high school landscapes: Examining the links. Landscape and Urban Planning 97:273–282.

Mccoy, L. P. 2005. Effect of Demographic and Personal Variables on Achievement in Eighth-Grade Algebra. The Journal of Educational Research 98:131–135.

Mueller, M. A. E., and E. Flouri. 2021. Urban Adolescence: The Role of Neighbourhood Greenspace in Mental Well-Being. Frontiers in Psychology 12.

National School Lunch Program (NSLP) | Feeding America. (n.d.). . https://www.feedingamerica.org/take-action/advocate/federal-hunger-relief-programs/national-school-lunch-program.

National Teacher and Principal Survey (NTPS). (n.d.). . National Center for Education Statistics. https://nces.ed.gov/surveys/ntps/tables/ntps1718_fltable06_t1s.asp.

Navarrete-Hernandez, P., and K. Laffan. 2019. A greener urban environment: Designing green infrastructure interventions to promote citizens' subjective wellbeing. Landscape and Urban Planning 191:103618.

O'Brien, L., A. Burls, P. Bentsen, I. Hilmo, K. Holter, D. Haberling, J. Pirnat, M. Sarv, K. Vilbaste, and J. McLoughlin. 2011. Outdoor Education, Life Long Learning and Skills Development in Woodlands and Green Spaces: The Potential Links to Health and Well-Being. Pages 343–372 *in* K. Nilsson, M. Sangster, C. Gallis, T. Hartig, S. de Vries, K. Seeland, and J. Schipperijn, editors. Forests, Trees and Human Health. Springer Netherlands, Dordrecht.

Odgers, C. L., A. Caspi, C. J. Bates, R. J. Sampson, and T. E. Moffitt. 2012. Systematic social observation of children's neighborhoods using Google Street View: a reliable and cost-effective method. Journal of Child Psychology and Psychiatry 53:1009–1017.

Plans, E., P. Gullón, A. Cebrecos, M. Fontán, J. Díez, M. Nieuwenhuijsen, and M. Franco. 2019. Density of Green Spaces and Cardiovascular Risk Factors in the City of Madrid: The Heart Healthy Hoods Study. International Journal of Environmental Research and Public Health 16:4918.

R Core Team. 2022. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Raney, M. A., C. F. Hendry, and S. A. Yee. 2019. Physical Activity and Social Behaviors of Urban Children in Green Playgrounds. American Journal of Preventive Medicine 56:522–529.

Reid, C. E., J. E. Clougherty, J. L. C. Shmool, and L. D. Kubzansky. 2017. Is All Urban Green Space the Same? A Comparison of the Health Benefits of Trees and Grass in New York City. International Journal of Environmental Research and Public Health 14:1411.

Roe, J., and P. Aspinall. 2011. The restorative outcomes of forest school and conventional school in young people with good and poor behaviour. Urban Forestry & Urban Greening 10:205–212.

Roe, J. J., C. W. Thompson, P. A. Aspinall, M. J. Brewer, E. I. Duff, D. Miller, R. Mitchell, and A. Clow. 2013. Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. International Journal of Environmental Research and Public Health 10:4086–4103.

Schüle, S. A., K. M. A. Gabriel, and G. Bolte. 2017. Relationship between neighbourhood socioeconomic position and neighbourhood public green space availability: An

environmental inequality analysis in a large German city applying generalized linear models. International Journal of Hygiene and Environmental Health 220:711–718.

Seo, S., S. Choi, K. Kim, S. M. Kim, and S. M. Park. 2019. Association between urban green space and the risk of cardiovascular disease: A longitudinal study in seven Korean metropolitan areas. Environment International 125:51–57.

Shapiro, H. S., and D. E. Purpel. 2004. Critical Social Issues in American Education: Democracy and Meaning in a Globalizing World. Routledge.

Shen, Y.-S., and S.-C. C. Lung. 2016. Can green structure reduce the mortality of cardiovascular diseases? Science of The Total Environment 566–567:1159–1167.

Shin, W. S. 2007. The influence of forest view through a window on job satisfaction and job stress. Scandinavian Journal of Forest Research 22:248–253.

Sidanius, J., and F. Pratto. 1999. Social dominance: An intergroup theory of social hierarchy and oppression. Pages x, 403. Cambridge University Press, New York, NY, US.

Smith, L. L., and C. E. Motsenbocker. 2005. Impact of Hands-on Science through School Gardening in Louisiana Public Elementary Schools. HortTechnology 15:439–443.
MISSING SMITH ET AL.

Steele, C. M., S. J. Spencer, and J. Aronson. 2002. Contending with group image: The psychology of stereotype and social identity threat. Pages 379–440 Advances in Experimental Social Psychology. Academic Press.

Stevenson, K. T., R. Moore, N. Cosco, M. F. Floyd, W. Sullivan, L. Brink, D. Gerstein, C. Jordan, and J. Zaplatosch. 2020. A national research agenda supporting green schoolyard development and equitable access to nature. Elementa: Science of the Anthropocene 8:406.

Tallis, H., G. N. Bratman, J. F. Samhouri, and J. Fargione. 2018. Are California Elementary School Test Scores More Strongly Associated With Urban Trees Than Poverty? Frontiers in Psychology 9.

Turner-Skoff, J. B., and N. Cavender. 2019. The benefits of trees for livable and sustainable communities. PLANTS, PEOPLE, PLANET 1:323–335.

Ulrich, R. S., R. F. Simons, B. D. Losito, E. Fiorito, M. A. Miles, and M. Zelson. 1991. Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology 11:201–230.

Wallner, P., M. Kundi, A. Arnberger, R. Eder, B. Allex, L. Weitensfelder, and H.-P. Hutter. 2018. Reloading Pupils' Batteries: Impact of Green Spaces on Cognition and Wellbeing. International Journal of Environmental Research and Public Health 15:1205.

Ward Thompson, C., J. Roe, P. Aspinall, R. Mitchell, A. Clow, and D. Miller. 2012. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. Landscape and Urban Planning 105:221–229.

Wells, N. M. 2000. At Home with Nature: Effects of "Greenness" on Children's Cognitive Functioning. Environment and Behavior 32:775–795.

Wells, N. M., and G. W. Evans. 2003. Nearby Nature: A Buffer of Life Stress among Rural Children. Environment and Behavior 35:311–330.

White, M. P., I. Alcock, B. W. Wheeler, and M. H. Depledge. 2013. Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. Psychological Science 24:920–928.

Wilson, R. 2007. Nature and Young Children: Encouraging Creative Play and Learning in Natural Environments. Routledge, London.

Wu, C.-D., E. McNeely, J. G. Cedeño-Laurent, W.-C. Pan, G. Adamkiewicz, F. Dominici, S.-C. C. Lung, H.-J. Su, and J. D. Spengler. 2014. Linking Student Performance in Massachusetts Elementary Schools with the "Greenness" of School Surroundings Using Remote Sensing. PLOS ONE 9:e108548.