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Impact of environmental programs on student test scores mediated by school attendance rate

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ABSTRACT

Background: Little is known regarding whether environmental programs affect student academic performance. We examined if the association between EPA Tools for School (TfS) policies or other environmental programs and student test scores were mediated by student attendance.

Methods: The 2015 School Building Condition Survey (BCS) was linked with School Report data provided by the New York State Education Department (NYSED). BCS includes school building information from 2,956 public schools while School Report data provides school attendance and test scores for different subjects in NYS. We conducted causal mediation analysis to investigate direct and indirect effects of TfS or other programs, via improving attendance, on test scores for each course while controlling for school-level socio-demographics.

Results: EPA TfS policies were significantly associated with a lower percent of "low total score" for overall math, overall science, and multiple specific subjects (all $P < 0.05$). Furthermore, the associations between TfS and test scores in algebra II, trigonometry, and chemistry were significantly mediated by student attendance rate (-1.376 and -0.563 respectively). Other IAQ programs were also associated with a smaller percent of low-score students in multiple subject tests (all $P < 0.05$). We found a mediated proportion of 6 to 43% by attendance in the association between other IAQ programs and high score academic performance. Implementing TfS and other programs can reduce the proportion of students receiving overall low scores by 2.66% and 1.37%, respectively.

Conclusion: EPA TfS and other IAQ programs improved student test scores in multiple subjects in NYS public schools and was partially mediated by improving attendance rate.

Introduction and background

Children spend the majority of their daily time attending school (Annesi-Maesano et al., 2013) where the environment is a potential factor when assessing student health status, attendance, and academic performance. As reported by the U.S. Environmental Protection Agency (EPA), environmental problems such as indoor air quality (IAQ) give rise to short and long-term health concerns for both students and staff ("Why Indoor Air Quality is Important to Schools |Creating Healthy Indoor Air Quality in Schools | U.S., 2021,"). Children, who are in a critical period of physiological development, are believed to be more vulnerable than adults and several studies indicate that air pollution in school is associated with declines in student health, academic performance, and attendance rate (Mohai et al., 2011; Park et al., 2002). In addition, indoor air pollution is a more significant health concern compared to outdoor, since concentrations of indoor air pollutants could be much greater than their outdoor concentrations (EPA) and the majority of the population usually spend 90 percent of their daily time indoors, according to EPA's estimation (EPA). Moreover, other studies also reported that worse quality buildings like physical defects and lack of proper ventilation were related to decreases in reading and math skills, while chronic absences increased by 0.75%.

Based on this, the EPA created indoor air quality (IAQ) tools for school (TfS) to provide favorable environments for student health and learning. The EPA TfS program provides strategies and a robust suite of tools to help schools identify, correct, and reduce environmental health and safety risks (Moglia et al, 2006). This strategy has been used to help several school districts improve their environment ("Healthy School En-

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vironments | U.S., 2021,"). For instance, the Salt Lake City School District's relative humidity and carbon dioxide were improved as a result of better IAQ management by using EPA TfS (United States Environmental Protection Agency, 2014). In the Hartford case study, IAQ planning via EPA TfS implementation was linked to decreased asthma-related nurse visits. In Minnesota, improvements in carbon dioxide and dust concentrations led to declines in allergy and asthma-related triggers. Approximately 40.7% of respondents reported improved perceptions of IAQ in their classrooms after implementation of EPA TfS.

Although many studies have investigated which environmental factors in schools are associated with student health status, school attendance, and academic performance (Mohai et al., 2011; Park et al., 2002), several knowledge gaps still exist. (1) Most previous studies only focused on the relationships between school environmental factors and school attendance, ignoring the important modifying effect of environmental programs; (2) no prior research examined how environmental programs affected student test scores, especially as mediated by the student's attendance; (3) apart from EPA TfS programs, prior research did not evaluate other IAQ management programs with regard to improving school environment; (4) when assessing academic performance, previous work only included a total of summary scores instead of subject-specific test scores; and (5) prior research that included mediation analysis was not clear about the proportion of mediation effects that environmental programs have on mediating student academic performance through school attendance.

To fill these knowledge gaps, in this study we aimed to (1) investigate the direct effects of the EPA TfS program and other IAQ programs on student academic performance and school attendance; (2) examine the proportion of mediation effects of school attendance on student academic performance through the EPS TfS and other programs; and (3) examine the total effects of TfS and other environmental programs on student academic performance.

Methods

Data sources and collection

Two datasets were used in the analysis. The first came from the 2015 New York State (NYS) Building Condition Survey (BCS). NYS Education Law and regulations mandate that all NYS public schools submit the BCS to NYS Education Department (NYSED) every 5 years to assess their environment with respect to building conditions and student learning environments. The BCS aims to measure building systems and school environment using a group of licensed engineers or architects through physical inspection. The BCS also includes items on school building age, size, and ratings of the overall building condition which includes 53 individual building systems. These include envelope, plumbing systems, heating ventilation and air conditioning (HVAC) systems, and roofing. Since 2005, a new section assessing environmental parameters related to comfort and health, including IAQ, cleanliness, acoustics, and lighting has been added.

The second dataset comes from the NYSED and includes all school-level academic information for students [Regent test results for high school students, English language arts (ELA), mathematics ("NY State - New Yor state report card [2018 - 19]), science for middle school students] in 2016. Both datasets contain school geographical information, which was used to link the data records.

Study design and study population

This is a cross-sectional study using data from all public elementary, middle, and high schools (698 schools) in NYS, excluding New York City (NYC) for which BCS data was not available. Our analysis included 695 schools and was based on school-level information for both school environment and student academic performance (middle and high school) at each participating school, using a standardized, structured BCS questionnaire.

Outcome definition

The outcome in this study was student low-score percentage for different courses including English, math (algebra I, algebra II, and geometry), science (chemistry, earth science, living environment, and physics), ELA, and social studies (global history and U.S. history). In the original dataset, the academic information showed the number of students who received a score lower than 65 points, between 65 and 85 points, and above 85 points. We defined these categories as low-score performance, medium-score performance, and high-score performance, respectively. We used the percentage of students in each category (L for percentage of low-score performance, N for percentage of medium-score performance, and H for percentage of high-score performance) in which the numerator is the number of students in each category and the denominator is the total number of students in the school.

Predictor and confounders

The major predictor that our study focused on was the EPA TfS and other IAQ programs. We compared student academic performance with the existence or absence of environmental programs. EPA TfS and other IAQ programs were treated as binary variables in the study (Moglia et al., 2006). Other IAQ programs refers to management plans which are applied to schools in NYS to improve their indoor air quality. Information mentioned above can be found in the BCS. We also included free lunch, gender, race, and ethnicity in each school as confounders in the model, and these variables can be accessed from NYSED website ("NY state New York state report card [2018 - 19] 2021").

Mediator definition

In the mediation analysis model, we define the school-level high student attendance rate (above 50% percentile of all schools' attendance rate) as the mediator, which plays an important role in regulating the relationship between environmental programs (EPA TfS and other IAQ programs) and students' low score performance percentage. Information can be found in the dataset as the outcomes from the NYSED website.

Statistical analysis

First, based on our school-level data (each row represents a school while each column represents a variable), we estimated the percent of students with low (L), medium (M), or high (H) academic performance in each school. We then dichotomized the three variables at the 50th percentile to generate three indicators of low/high L-percent schools, low/high M-percent schools, and low/high H-percent schools. We defined a school with low L-percent, high M-percent, and high H-percent as a "Good-performance school"; a school with high L-percent, low M-percent, and low H-percent as a "Poor-performance school"; while all others were defined as "Fair-performance schools." We examined the association of EPA TfS and other IAQ programs with categorized student academic performance for different subjects using a multinomial logistic regression model controlling for socio-economics status (SES). We calculated odds ratios (ORs) and their 95% confidence intervals (CIs) with exponentiation of regression coefficients using multinomial logistic regression model as follows:

$$ln\frac{P(S_i=0)}{P(S_i=3)} = \beta_{01}X_{1i} + \beta_{02}X_{2i} + \beta_{03}X_{3i} + \beta_{04}X_{4i} + \beta_{05}X_{5i} + \beta_{06}X_{6i}$$

$$ln\frac{P(S_i=1)}{P(S_i=3)} = \beta_{11}X_{1_i} + \beta_{12}X_{2_i} + \beta_{13}X_{3_i} + \beta_{14}X_{4_i} + \beta_{15}X_{5_i} + \beta_{16}X_{6_i}$$

$$ln\frac{P(S_i=2)}{P(S_i=3)} = \beta_{21}X_{1_i} + \beta_{22}X_{2_i} + \beta_{23}X_{3_i} + \beta_{24}X_{4_i} + \beta_{25}X_{5_i} + \beta_{26}X_{6_i}$$

where X_{1_i} and X_{2_i} are indicators of school i using EPA TfS and other IAQ programs, respectively. X_{1_i} $(X_{2_i}) = 1$ if IAQ programs are used, otherwise, X_{1_i} $(X_{2_i}) = 0$. $X_{3_i}, X_{4_i} X_{5_i}$ and X_{6_i} are confounders in the model. A $\chi 2$ test was also implemented to test the independence of student academic performance (S) and environmental programs (X_{1_i} and X_{2_i}). We dichotomized the continuous variable attendance rate at the 50th percentile to generate an indicator of high attendance rate, and we assessed the association of IAQ programs with school high attendance rate in elementary, middle, and high schools, respectively, using logistic regression model. The association between school high attendance rate and student low-score performance rate (L) was also assessed by using a linear regression model. Finally, we adopted causal mediation analysis model to assess the mediation effect of school high attendance rate (M) on the association of EPA TfS (P_1) and other IAQ programs (P_2) with students' percentage of low-score performance (L) in different subjects. The framework of the mediation analysis model is constructed by regression formulas as follows:

$$M = \alpha_0 + aP_1 + \epsilon_1$$

$$M = \alpha_1 + a'P_2 + \epsilon_2$$

$$L = \alpha_2 + c_1P_1 + \epsilon_3$$

$$L = \alpha_3 + c_2P_2 + \epsilon_4$$

$$L = \alpha_4 + bM + c_3P_1 + \epsilon_5$$

$$L = \alpha_5 + b'M + c_4P_2 + \epsilon_6,$$

where α_0, α_1, α_2, α_3, α_4, and α_5 are intercepts; a, a', b, b', c_1, c_2, c_3,and c_4 are regression coefficients; and ϵ_1, ϵ_2, ϵ_3, ϵ_4, ϵ_5, and ϵ_6 are error terms for corresponding regression equations. The effect of attendance rate on mediating environmental programs and students' low-score performance are calculated as ab and $a'b'$ for EPA TfS and other IAQ programs, respectively. The direct effect of environmental programs on students' low score performance are measured by c_3 and c_4. The proportion of mediation effect is measured by $\frac{ab}{ab+c_3}$ and $\frac{a'b'}{a'b'+c_4}$ for EPA TfS and other IAQ programs, respectively. For statistical computations, we used the

Table 1
Impacts (risk ratios, RR) of EPA TfS and other IAQ programs on students' test scores in NYS public school (n = 698).

	School used EPA TfS		School used other IAQ programs	
Subject	Score#	RR (95%CI)	Score#	RR (95%CI)
Overall	Low	0.97 (0.83, 1.07)	Low	0.89 (0.72, 0.99)
	Medium	1.10 (1.01, 1.17)	Medium	0.94 (0.91, 0.96)
	High	1.00 (ref)	High	1.00 (ref)
Math	Low	0.94 (0.74, 1.07)	Low	0.82 (0.59, 0.98)
	Medium	1.02 (0.83, 1.14)	Medium	0.84 (0.58, 1.02)
	High	1.00 (ref)	High	1.00 (ref)
Algebra	Low	0.82 (0.76, 0.89)	Low	0.61 (0.54, 0.69)
	Medium	0.93 (0.86, 1.01)	Medium	0.59 (0.53, 0.65)
	High	1.00 (ref)	High	1.00 (ref)
Algebra II/trigonometry	Low	0.94 (0.91, 0.98)	Low	0.98 (0.92, 1.04)
	Medium	0.98 (0.95, 1.01)	Medium	1 (0.96, 1.04)
	High	1.00 (ref)	High	1.00 (ref)
Geometry	Low	1.05 (0.99, 1.11)	Low	0.91 (0.86, 0.97)
	Medium	1.14 (1.11, 1.17)	Medium	0.84 (0.81, 0.88)
	High	1.00 (ref)	High	1.00 (ref)
English Language Art	Low	1.22 (1.15, 1.3)	Low	0.79 (0.74, 0.83)
	Medium	1.18 (1.16, 1.21)	Medium	0.93 (0.91, 0.96)
	High	1.00 (ref)	High	1.00 (ref)
Science	Low	0.86 (0.82, 0.88)	Low	1.03 (0.93, 1.10)
	Medium	1.06 (0.99, 1.11)	Medium	0.94 (0.94, 1.00)
	High	1.00 (ref)	High	1.00 (ref)
Chemistry	Low	0.86 (0.8, 0.93)	Low	1.03 (0.95, 1.11)
	Medium	1.05 (1.02, 1.09)	Medium	0.95 (0.91, 0.99)
	High	1.00 (ref)	High	1.00 (ref)
Earth science	Low	0.84 (0.81, 0.88)	Low	1.09 (1.03, 1.16)
	Medium	1.13 (1.1, 1.16)	Medium	0.89 (0.86, 0.91)
	High	1.00 (ref)	High	1.00 (ref)
Living Environment	Low	0.85 (0.82, 0.89)	Low	1.06 (1, 1.13)
	Medium	1.03 (1.01, 1.05)	Medium	1.02 (0.99, 1.05)
	High	1.00 (ref)	High	1.00 (ref)
Physics	Low	0.91 (0.85, 0.99)	Low	0.92 (0.84, 1.02)
	Medium	1.04 (1, 1.09)	Medium	0.88 (0.83, 0.93)
	High	1.00 (ref)	High	1.00 (ref)
Social science	Low	1.04 (0.97, 1.08)	Low	0.91 (0.74, 1.01)
	Medium	1.11 (1.08, 1.12)	Medium	0.96 (0.91, 0.99)
	High	1.00 (ref)	High	1.00 (ref)
Global History	Low	1.02 (0.98, 1.06)	Low	0.96 (0.92, 1)
	Medium	1.1 (1.08, 1.13)	Medium	0.97 (0.95, 1)
	High	1.00 (ref)	High	1.00 (ref)
US. History	Low	1.07 (1.01, 1.14)	Low	0.85 (0.8, 0.9)
	Medium	1.11 (1.08, 1.13)	Medium	0.96 (0.94, 0.99)
	High	1.00 (ref)	High	1.00 (ref)

*For the score # column, "Low" represents the risk ratio (RR) of the categorized low-score performance of students who received a grade lower than 65 points. "Medium" represents the number of students who received a grade between 65 and 85. "High" represents the number of students who received a grade higher than 85 points which was served as the reference group.

"mediate" function from the "mediation" package in R, and calculated the total effect, direct effect, indirect effect, and proportion mediated. We used R 3.6.1 (R Core Team (2014). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria (http://www.R-project.org/). For all analyses, statistical significance was defined as P <0.05 for a 2-tailed test.

Results

Table 1 shows how EPA TfS and other IAQ programs impact student academic performance. The significant results of the $\chi 2$ test of independence showed that there were associations between environmental programs and student academic performance. EPA TfS and other IAQ programs reduced students' low-score performance by 3% (RR: 0.97, 95% CI: 0.83, 1.07) and 11% (RR: 0.89, 95% CI: 0.72, 0.99), respectively. EPA TfS significantly reduced low-score performance for science (14%, RR: 0.86, 95% CI: 0.82, 0.88), especially for chemistry (16%, RR: 0.84, 95% CI: 0.80, 0.93). Other IAQ programs reduced overall low-score performance by 11% (RR:0.89, 95% CI: 0.72, 0.99). Other IAQ programs reduced low-score performance in math by 18% (RR:0.82, 95% CI: 0.59, 0.98), especially in algebra (39%, RR:0.61, 95% CI:0.54, 0.69).

Table 2 shows how EPA TfS and other IAQ programs impact student attendance by stratified analysis. EPA TfS and other IAQ programs increased overall students' high attendance rate by 4% (RR: 1.04, 95% CI: 0.95, 1.14) and 8% (RR: 1.08, 95% CI: 1.06, 1.12), respectively. Both EPA TfS and other IAQ programs significantly increased the attendance rate for elementary, middle, and high school students. Implementing EPA TfS increased the high attendance rate probability for elementary and middle school student attendance rate by 27% (RR: 1.27, 95% CI: 1.06, 1.52) and for high school students by 18% (RR:1.18, 95% CI: 1.04, 1.34). Employing other IAQ programs increased the high attendance rate probability for elementary and middle school students by 32% (RR: 1.32, 95% CI: 1.10, 1.59) and high school students by 14% (RR: 1.14, 95% CI: 1.00, 1.13).

Table 3 shows the impact of high attendance rate on student academic performance in each subject. Increasing attendance rate significantly decreased the percentage of students who scored low and increased the percentage of students who scored high across all subjects. Overall, we found that a one percent increase in attendance rate decreased the number of students who scored low by 0.53% (p-value < 0.001) and increased the number of students who scored high by 0.63% (p-value < 0.001). We also found that a one percent increase in attendance rate lowered the number of students who scored low in math by 0.66% (p-value < 0.001), especially for trigonometry (1.19%, p-value < 0.001). In addition, we found that a one percent increase in attendance rate increased the number of students who scored high in science by 0.79% (p-value < 0.001), especially for living environment (1.03%, p-value < 0.001) and physics (0.78%, p-value < 0.001).

Fig. 1 illustrates how the relationship between EPA TfS/other IAQ programs and student test scores is mediated by attendance rate. Environmental programs directly affect student test scores by providing school environments that are more comfortable and conducive to learning. Environmental programs also indirectly affect student test scores by improving attendance rate. Schools with environmental programs tend to have lower concentrations of indoor pollutants which improves student health and, in turn, student attendance rate. Similarly, students who miss less school tend to perform better on tests.

Table 3
High attendance rate impact different student performance level.

Subject	Score %	Beta estimate of attendance rate	P-value
Overall	High	0.63	<0.001
	Medium	-0.51	<0.001
	Low	-0.53	<0.001
Math	High	0.44	<0.001
	Medium	-0.37	<0.001
	Low	-0.66	<0.001
Algebra	High	0.11	0.06
	Medium	0.11	0.07
	Low	-0.22	<0.001
Algebra II/trigonometry	High	0.77	<0.001
	Medium	-0.66	<0.001
	Low	-1.19	<0.001
Geometry	High	0.44	<0.001
	Medium	-0.56	<0.001
	Low	-0.57	<0.001
English Language Art	High	0.64	<0.001
	Medium	-0.36	<0.001
	Low	-0.34	<0.001
Science	High	0.79	<0.001
	Medium	-0.44	<0.001
	Low	-0.55	<0.001
Chemistry	High	0.69	<0.001
	Medium	-0.22	<0.001
	Low	-0.60	<0.001
Earth science	High	0.65	<0.001
	Medium	-0.60	<0.001
	Low	-0.36	<0.001
Living Environment	High	1.03	<0.001
	Medium	-0.34	<0.001
	Low	-0.56	<0.001
Physics	High	0.78	<0.001
	Medium	-0.60	<0.001
	Low	-0.66	<0.001
Social science	High	0.65	<0.001
	Medium	-0.88	<0.001
	Low	-0.56	<0.001
Global History	High	0.54	<0.001
	Medium	-0.57	<0.001
	Low	-0.60	<0.001
US. History	High	0.76	<0.001
	Medium	-1.19	<0.001
	Low	-0.51	<0.001

*For the different score percentage column, "Low Score %" represents the percentage of students who received a grade lower than 65 points. "Medium Score %" represents the percentage of students who received a grade between 65 and 85. "High Score %" represents the percentage of students who received a grade higher than 85 points

Table 2
EPA TfS and other IAQ programs and high attendance in NYS public schools.

SES-Grade		RR (95%CI) EPA TfS	RR (95%CI) Other IAQ programs
Overall		1.04 (0.95, 1.14)	1.48 (1.36, 1.62)
Race	Black	1.07 (1.01, 1.20)	1.15 (0.95, 1.37)
	White	1.02 (0.90, 1.17)	1.18 (1.02, 1.37)
Economic status	Economically Advantaged	1.03 (0.90, 1.18)	1.17 (1.01, 1.36)
	Economically Disadvantaged	0.97 (0.85, 1.12)	1.26 (1.08, 1.46)
Ethnicity	Hispanic	1.06 (0.91, 1.24)	1.05 (0.88, 1.25)
Grade	Elementary/Middle School	1.27 (1.06, 1.52)	1.32 (1.10, 1.59)
	High School	1.18 (1.04, 1.34)	1.14 (1.00, 1.30)

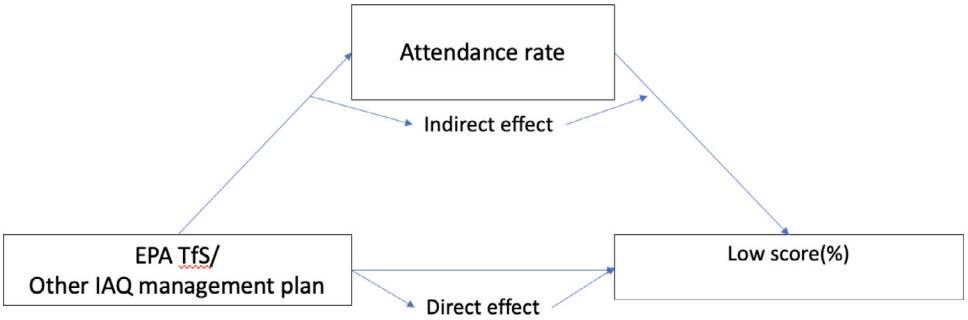

Fig. 1. Mediation Effect relation figure. *Total effect = direct effect + indirect effect

Table 4
Direct, indirect and total effect EPA TfS/Other IAQ programs on student poor performance.

Subject	Indirect effect	p-value	Direct effect	p-value	Total effect	p-value
EPA tools for school						
Overall	-0.217	0.40	-2.44	0.09	-2.66	0.09
Math	-0.175	0.40	-3.31	<0.001	-3.49	<0.001
Algebra I	0.042	0.72	-1.67	0.04	-1.63	0.04
Algebra II/trigonometry	-1.376	<0.001	-1.56	0.16	-2.94	0.02
Geometry	-0.278	0.30	-2.31	0.02	-2.58	0.02
English language arts	-0.152	0.42	-0.82	0.16	-0.98	0.14
Science	-0.240	0.40	-2.75	<0.001	-2.99	<0.001
Chemistry	-0.563	<0.001	-1.88	0.02	-2.45	<0.001
Earth science	-0.041	0.86	-1.98	0.02	-2.03	0.02
Living environment	-0.220	0.38	-0.92	0.06	-1.15	0.04
Physics	-0.445	0.10	-1.92	0.04	-2.36	0.02
Social science	-0.300	0.40	-2.88	0.20	-3.17	0.20
Global history	-0.231	0.54	0.82	0.34	0.58	0.54
US. history	-0.217	0.44	<0.001	0.94	-0.21	0.80
Other IAQ programs						
Overall	-0.531	0.31	-1.135	0.26	-1.37	0.35
Math	-0.134	0.80	-0.61	0.80	-0.74	0.80
Algebra I	-0.269	0.14	-0.17	0.86	-0.44	0.58
Algebra II/trigonometry	0.369	0.50	0.55	0.66	0.92	0.54
Geometry	-0.538	0.14	1.62	0.10	1.09	0.34
English language arts	-0.461	0.04	0.87	0.24	0.40	0.58
Science	-0.240	0.40	0.735	<0.001	2.75	<0.001
Chemistry	0.129	0.62	1.52	0.06	1.65	0.06
Earth science	-0.196	0.34	0.88	0.30	0.68	0.44
Living environment	-0.687	<0.001	-0.03	1	-0.71	0.28
Physics	-0.007	0.98	0.57	0.50	0.56	0.64
Social science	-1.290	<0.001	-2.13	<0.001	-3.78	<0.001
Global history	-0.907	<0.001	-1.11	0.16	-2.02	0.04
U.S. history	-0.739	<0.001	-1.02	0.12	-1.76	0.02

Table 4 shows the direct, indirect, and total effects of EPA TfS and other IAQ programs on student academic performance. EPA TfS policies indirectly lowered students' overall low-score academic performance 0.217% by increasing the attendance rate 1%. This relationship was especially strong for algebra II/trigonometry (1.376%, p-value < 0.001) and chemistry (0.563%, p-value < 0.001). In addition, implementation of EPA TfS policies directly reduced students' overall low-score performance 2.44% by improving IAQ.

Other IAQ programs indirectly lowered students' overall low-score academic performance 0.531% by increasing high attendance rate by 1%. This relationship was especially strong for English (0.461%, p-value = 0.04) and living environment (0.687%, p-value < 0.001). Implementation of other IAQ programs also directly reduced students' overall low-score performance by 1.135%.

Fig. 2a shows the extent to which school attendance mediates the effect of EPA TfS on test scores. EPA TfS policies increased the mediation effect of school attendance by 47% in algebra II/trigonometry, 31% in U.S. history, 23% in chemistry, 19% in living environment, 18% in physics, 13% in English, 2% in earth science, and 1% in geometry. These environmental programs also decreased the mediation effect of school attendance by 6% in global history and 2% in algebra I. The variance of this mediation effect was largest for U.S. history, relatively large for global history, and relatively small for all other subjects.

Fig. 2b shows the extent to which school attendance mediates the effect of other environmental programs on test scores. Other IAQ programs increased the mediation effect of school attendance by 82% in living environment, 43% in global history, 41% in U.S. history, 27% in algebra II/trigonometry, 25% in algebra I, 8% in chemistry, and 6% in physics. These environmental programs also decreased the mediation effect on school attendance by 34% in English, 28% in geometry, and 9% in earth science.

Discussion

EPA TfS, other IAQ programs, and test scores

We found that EPA TfS and other IAQ programs were significantly associated with a reduced probability of receiving low test scores in math (especially algebra and geometry), science (especially earth science), social science (especially global history), and English/language arts. No previous studies are available to compare with our findings. However, it is plausible that EPA TfS and similar programs may im-

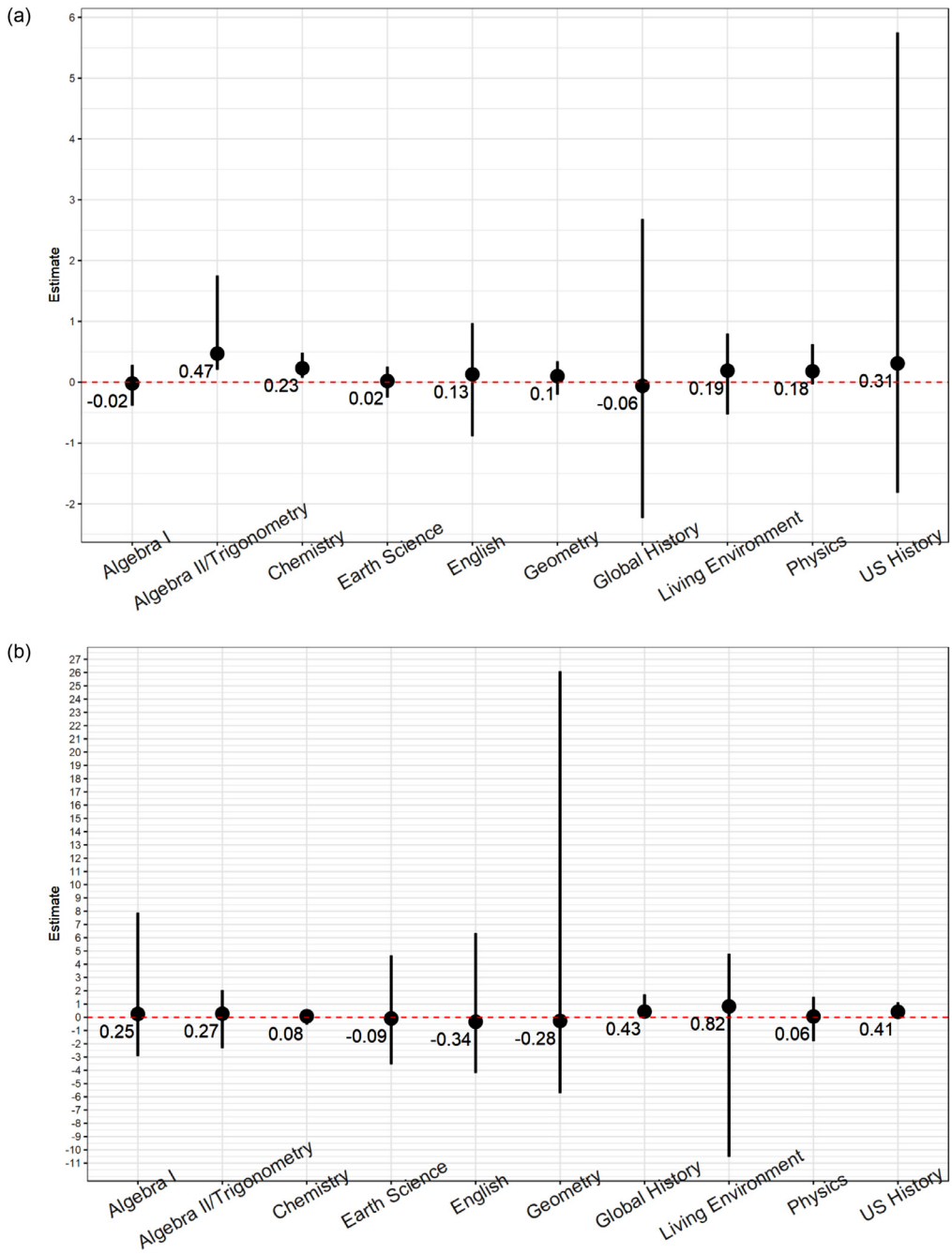

Fig. 2. (a) Proportion of mediation effect (school attendance) estimate for EPA TfS-test score relationship. * Proportion of mediation effect=the proportion of the exposure's effect on the outcome that mediated by another factor (i.e. mediator). (b) Proportion of mediation effect (school attendance) estimate for other IAQ programs -test score relationship. * Proportion of mediation effect=the proportion of the exposure's effect on the outcome that mediated by another factor (i.e. mediator)

prove test scores by improving IAQ. Previous studies have reported that controlling the quantity of potentially hazardous air-borne pollutants through ventilation and air conditioning (HVAC) systems may help improve IAQ in schools (Axelrad, 2006). Although there were no established direct associations between IAQ and student academic performance in this study, IAQ likely affects student health status and, in turn, would significantly decrease their academic performance. Previous researchers found that air pollution significantly jeopardized children's health and that poor health conditions had a negative impact on student academic performance (Geller et al., 2007; Mohai et al., 2011b). Researchers also demonstrated that school building quality had a significantly positive relationship with student academic performance (Lorrain et al., 2012). Finally, Shaughnessy et al. (2006) reported a borderline significant association between classroom-level ventilation rate and student academic performance in math.

EPA TfS, other IAQ programs, and student attendance rate

We found that EPA TfS and other IAQ programs were significantly correlated with increased student attendance rate. The aim of employing EPA TfS and other similar programs is to improve IAQ, and they

have been found to be effective (US EPA, 2014). There is previous literature to support the association between air quality at school and student attendance rate. Maxwell (2016) reported that higher air quality (fewer potentially hazardous air-borne pollutants through heating, ventilation, etc.) significantly increased middle school student attendance rate in NYC (direct effect of 0.26 under mediation analysis model). Shendell et al. (2004) explored the association between student attendance rate and the difference between outdoor and indoor carbon dioxide concentrations (dCO^2). They reported that an increase in dCO^2 was significantly associated (p-value < 0.05) with a decrease in student attendance rate.

Student attendance rate and test scores

We found that increasing attendance rate significantly reduced the probability of receiving low test scores. Maxwell (2016) reported a significant impact of attendance rate on ELA scores (direct effect is 0.39 under mediation analysis model) for middle school students in NYC. Attending school is one of the most important times during which students gain knowledge. Previous research supports this claim by showing that school attendance rate was significantly related with student academic performance. Gottfried (2010) reported a positive linear association between student attendance rate and academic achievement (GPA) in a Philadelphia primary school district. Chen and Lin (2008) indicated that attending lectures significantly improved student exam performance in public finance by 9.4-18% in Taiwan using a randomized experimental approach.

Attendance rate as a mediator between environmental programs and test scores

We found that attendance rate played an important role mediating the pathway between the impact of EPA TfS/other IAQ management programs and student academic performance. EPA TfS and other IAQ programs are most likely related to test scores (overall effect: -2.66 and -1.37%, respectively) by impacting attendance rate. Higher attendance rate could be the result of improved air quality and subsequent improvement in students' health status. In addition, common health problems that hinder school attendance such as asthma and respiratory disease are highly related to IAQ (Neidell, 2004; Schwartz, 1993). EPA TfS and other IAQ programs were found to be effective at improving IAQ (U.S. EPA, 2014). These improvements then increased student attendance rate and thus reduced the rate of poor performance on tests. This is how attendance rate acts as a mediator for the association between environmental programs and test scores.

EPA TfS and other IAQ programs affected student academic performance both directly (overall effect: -2.44 and -1.135%, respectively) and indirectly (mediation effect: -0.217 and -0.531%, respectively). We found that EPA TfS and other IAQ programs directly reduce students' poor academic performance. Additionally, these programs indirectly reduced students' poor performance at school by increasing student attendance rate. Previous researchers also demonstrated that better IAQ increased student attendance rate directly (Maxwell and Schechtman, 2012). Indirectly, school attendance rate played a significant role in mediating the effect of environmental programs on student academic performance.

Mediation effects of attendance on different test subjects

In our study, attendance rate had the highest proportion of mediation effects on the associations between EPA TfS and student academic performance in math (especially in trigonometry) and social science (especially in U.S. History). The relationships between other IAQ programs and student academic performance in science and social science were highly mediated by student attendance rate. Previous research has shown that school attendance rate partially mediated the effect of school building conditions on students' grades in ELA and math (Durán-Narucki, 2008). Previous research has also shown that people become more unpleasant and exhausted when CO_2 concentrations are above 3,000 ppm. This level of CO_2 also reduces human attention and the capacity to concentrate when subjects spend two to three hours in such conditions (Kajtár and Herczeg, 2012). Math and science classes need more intensive concentration on thinking and massive calculation comparing to other social science subjects. Cai et al. (2018) reported that learning math-related subjects requires the ability to concentrate. Therefore, test scores in math and science benefit most from environmental programs. Our results showed significant mediation effects by attendance rate between environmental programs and academic performance in math and science.

Strength and limitations

This study contains multiple strengths which contribute significantly to the field of IAQ research. To the best of our knowledge, this is the first study to determine the mediation effect of attendance rate on the relationship between environmental programs (EPA TfS and other IAQ programs) and student academic performance. We included a large number of schools in our study (all public schools) and the school BCS data is reliable and professionally collected. We also utilized the mediation analysis model to identify the mediation effect of attendance rate (which has never been determined before) on the relationship between environmental programs and student academic performance. More importantly, this mediation analysis can be utilized by school officials and policymakers when planning interventions to address both school environment and academic problems.

There are also several limitations of this study that should be mentioned. Although the total number of schools included in this study is large, only public schools were included, as we did not have the information for private and charter schools. As described in a previous study by Lu, the calculated percentages of students enrolled in private and charter schools are low in NYS. Lu reported that less than 15% of districts reported having greater than 15% of students enrolled in private and 11.5% students enrolled in charter schools, respectively. There might be some demographic-based difference between private and public schools. Students who attend private school are usually from wealthier families and may be exposed to fewer environmental hazards at home. However, compared to public schools, environmental health issues may be more prevalent in private schools due to a lack of state funding and unavailability of standardized state environmental programs or policies (only 18% of private schools have IAQ management program compared to 58% of public schools). Another limitation of this study is that public schools in NYC were not included due to the unavailability of BCS data in this region. Thus, the findings from this study may have limited generalizability. In addition, the data was collected at the school level and we do not have individual-level data. Therefore, we cannot control for some confounders which may affect a student's performance on tests, such as individual parental education level and family income. On the other hand, our findings based on school-level data could be used more readily by school district administrators and policymakers compared to data collected at the individual level.

Conclusions

We found that environmental programs (EPA TfS and other IAQ programs) had both significant direct and indirect impacts on reducing students' low academic performances in NYS. Student attendance rate significantly mediated the impacts of EPA TfS and other IAQ programs on student test scores, especially in math and science. Our findings provide direct evidence of the beneficial effects of EPA TfS and other IAQ programs in helping improve both attendance rate and student academic performance.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.heha.2022.100028.

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