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# Breathing Success: How Better Indoor Air Quality Transforms Student Health and Test Scores

This paper highlights the growing importance of IAQ in learning environments and dives deeper into how monitoring your IAQ positively affects the health and productivity of students.

WHITE PAPER
2024

## INTRODUCTION

In the complex landscape of educational success, a crucial thread often overlooked is the quality of the air students breathe within the walls of their learning environments. As students embark on their scholastic journeys, the air they breathe becomes more than just a backdrop; it becomes a silent influencer, shaping their physical well-being, cognitive abilities, and academic outcomes. In this article, we delve into the multifaceted impact of Indoor Air Quality (IAQ) on students, unraveling its connections to health, attendance, and academic performance.

Indoor air quality in school buildings is influenced by a myriad of pollutants that can either originate within a building or infiltrate from outdoor sources. These contaminants encompass a wide range, including particulates, fibers, mists, bioaerosols, and gases. Complicating matters further, indoor air pollutant concentration levels can vary both by time and location within a school building or even within a single classroom. Sources of pollutants include point sources (e.g., science storerooms), area sources (e.g., newly painted surfaces), and mobile sources (e.g., cars, buses, power equipment). Moreover, the fluctuation of pollutants over time, whether due to short-term activities like floor stripping or continuous processes such as mold growth in HVAC systems, adds to the challenge of maintaining optimal indoor air quality. Despite indoor air often containing contaminants at concentrations below occupational standards, establishing a direct correlation between specific health effects and exposures to particular pollutant concentrations remains challenging, particularly when significant exposures may result from low levels of pollutant mixtures.[i]

Managing IAQ in schools presents unique challenges, distinct from other buildings. Schools accommodate a higher density of occupants, with approximately four times as many individuals as office buildings for the same floor space.[ii] Tight budgets, where maintenance often receives substantial cuts, further compound the challenge. The diverse array of pollutant sources, including art and science supplies, industrial and vocational arts, home economic classes, and gyms, adds complexity. The extensive heating, ventilating, and air-conditioning equipment in schools places an additional strain on maintenance staff. Concentrated diesel exhaust exposure from school buses, varying operational challenges with school expansions, and the use of spaces not originally designed for school requirements further emphasize the necessity for vigilant indoor air quality management. Overall, proper maintenance of indoor air in schools is not merely a quality concern but encompasses the broader aspects of safety and stewardship of the investment in students, staff, and facilities.

## HEALTH

Failure to address IAQ problems can lead to a variety of health issues for students and staff, ranging from common nuisances like coughing and eye irritation to more severe conditions such as Legionnaire's disease or carbon monoxide poisoning. Additionally, IAQ problems can exacerbate respiratory illnesses, particularly asthma, impacting student attendance, comfort, and performance.[ii] Individuals particularly susceptible to the effects of indoor air contaminants include those with allergies, chemical sensitivities, respiratory diseases, suppressed immune systems, or contact lenses. Certain groups, such as those with heart disease, may face increased vulnerability to specific pollutants like carbon monoxide. What's more, children, with developing bodies and unique physiological characteristics, may be more susceptible to environmental exposures than adults.[ii]


The exposure of pupils to indoor air pollutants within school buildings raises substantial public concern due to potential severe health implications. Children inhale larger volumes of air in proportion to their body weights compared to adults, and their respiratory, immunological, reproductive, central nervous, and digestive systems are not fully matured. The varying routes of breathing between nasal and oral, along with differences in the efficacy of the nose in filtering aerosols, expose children's lungs to higher quantities of air pollutants.[iii]

Inhalation exposure to indoor air pollution has been linked to increased mortality rates, acute respiratory diseases, and asthma in children.[iv] The diverse responses of children's immune systems to indoor air exposures have led to the characterization of various chronic diseases and symptoms as Sick Building Syndrome.[v] Recognized indoor pollutants such as CO2, PM, VOCs, NOx, and ozone are acknowledged for causing severe health problems for both adults and children.[vi] The Classroom Air Quality (CAQ) is characterized by a complex mixture of contaminants, including VOCs, PM, aldehydes, bacteria, and molds, prompting health risk assessments based on standards from entities like the U.S. EPA, WHO, ASHRAE, and GB/T.[vii]

In addition, indoor thermal conditions within classrooms hold particular significance as school children exhibit greater vulnerability to adverse environmental stimuli compared to adults.[viii] Research literature highlights physiological differences, including distinct surface-area to mass ratios, sweating rates, metabolism, body temperature, and cardiac output, between children and adults.[ix] [x] Understanding these differences is crucial for ensuring that indoor environments in schools are optimized to foster the health and well-being of the student population.

**TEST SCORES**

Children, being a distinct segment of the population, are more vulnerable to the indoor environment. They breathe in a greater volume of air relative to their body weight and exhibit heightened sensitivity to heat, cold, and moisture. The consequences of poor indoor conditions on children's proper development are significant. Establishing a healthy learning environment not only reduces absence rates but also positively impacts test scores and enhances the overall productivity of both pupils and teachers.[iii]

Numerous studies have underscored the significant impact of indoor air quality (IAQ) on students' academic performance and cognitive abilities.[xi] [xii] For instance, a comprehensive study conducted by Haverinen-Shaughnessy and colleagues, involving 100 schools in the United States, revealed a direct association between classroom ventilation rates and students' academic achievements.[xiii] Notably, improvements in IAQ within classrooms led to measurable progress in mathematics and reading, as assessed through standardized tests. This correlation is substantiated by systematic reviews and a large cohort study involving over 8,000 children in the UK.[xiv] [xv]

Similarly, Hutter et al, in their examination of 436 schoolchildren in Austrian urban areas, observed reduced cognitive performance in classrooms with elevated concentrations of particulate matter ($PM_{10}$, $PM_{2.5}$), and CO2.[xvi] In a cohort study involving 60 Scottish schools, elevated CO2 levels were linked to lower average annual attendance and poorer individual test scores in reading, writing, and arithmetic.[xvii] This correlation persisted even after adjusting for socioeconomic status and the number of students per class. Experimental studies in Germany and Portugal, involving 20 cluster-randomized classrooms and 51 primary schools, respectively, further demonstrated that increased CO2 levels were associated with reduced short-term attention performance in students.[xviii] [xix]

A Spanish cohort study by Sunyer and colleagues, focusing on 19 schools in Barcelona, explored the impact of air pollution from road traffic on IAQ and subsequent consequences on school performance.[xx] The study revealed a positive trend (up to +13%) in cognitive development indicators, such as attention and memorization capacity, in schools with lower levels of traffic-related ultrafine particulate, carbon particles, and NO2. This correlation was reaffirmed through an annual extension of the study across 39 schools, emphasizing the pervasive influence of IAQ on the cognitive performance of school-aged children.[xxi]

In addition, a recent study conducted by researchers at the Yale School of Public Health shed light on the potential negative impact of air pollution, specifically $PM_{2.5}$ (fine particulate matter), on standardized test scores among public school students.[xxii] The study, which utilized extensive data from the North Carolina Education Research Data Center spanning from 2001 to 2018, tracked 2.8 million students.

Interestingly, the nonlinear model revealed a negative association between $PM_{2.5}$ exposure and math scores within the concentration range of 10 to 14 µg/m³ , suggesting a critical threshold for impact. Additionally, consistent negative associations were observed between $PM_{2.5}$ exposure and the risk of poor reading performance, particularly when exceeding 8 µg/m³.[xxiii]

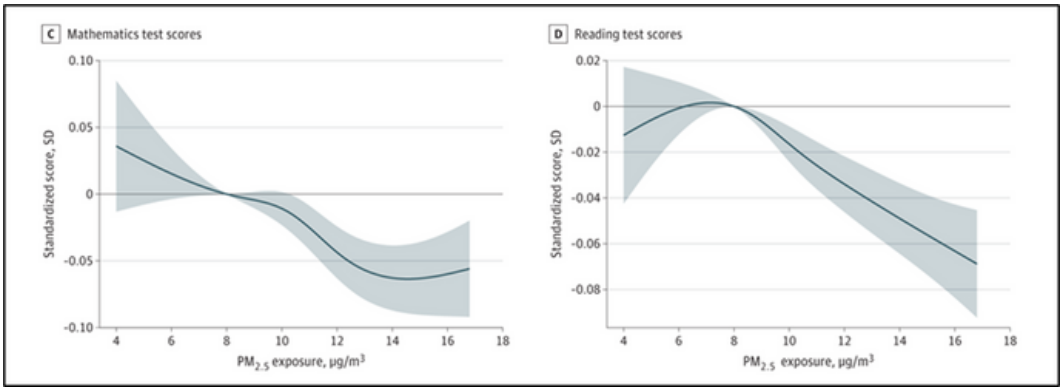


*Figure 1. Exposure to Particulate Matter ($PM_{2.5}$) vs. Test Scores*

The study's comprehensive dataset included diverse demographic groups, revealing significant disparities in susceptibility to $PM_{2.5}$ exposure. Notably, girls' math scores exhibited a higher susceptibility, and students with low family income experienced lower reading scores. Moreover, students from minority racial and ethnic backgrounds were found to be more affected by the same level of $PM_{2.5}$ exposure compared to White students.

Another research collaboration between The University of Tulsa, Oklahoma, and Brigham Young University in Provo, UT, assessed indoor environmental quality (IEQ) in schools and its impact on students' health and academic performance. The study, encompassing a 70-school district in the Southwestern United States over two academic years, collected data on temperature (T), relative humidity (RH), carbon dioxide (CO2), and settled dust. Additionally, student data related to socioeconomic background, absenteeism, performance, and visits to the school nurse were anonymously retrieved.[xxiv]

The findings revealed significant associations between indoor temperature, ventilation rate (calculated from CO2 levels), and the percentages of students scoring satisfactorily in mathematics and reading tests. Correlations between outdoor relative humidity and satisfactory test scores were likely linked to indoor temperature, which in turn is influenced by outdoor relative humidity. The study highlighted that higher room temperatures could lead to increased fatigue, reduced concentration, and hindered academic performance. Preliminary results from linear regression models suggested that low classroom temperature, coupled with a high ventilation rate, might be associated with higher rates of students scoring satisfactorily in mathematics and reading tests.

In another study, researchers from the London School of Economics and Political Science and Goucher College assessed the impact of school days and absences on test score performance among elementary school students.[xxv] Utilizing administrative data from North Carolina public schools, the researchers jointly estimated the effects of absences and the length of the school calendar on standardized test scores.

The study leveraged a state policy that provided variation in the number of school days prior to standardized testing and found notable differences between the effects of extended school days and reduced absences. Extending the school calendar by ten days resulted in modest increases of 1.7% and 0.8% of a standard deviation in math and reading test scores, respectively. In contrast, a similar reduction in absences led to more substantial gains of 5.5% in math and 2.9% in reading. Additionally, the negative impact of absences was found to be more pronounced among low-performing students, suggesting that the costs of catching up are higher for those facing greater difficulties in school. The study also revealed persistent effects of absences in subsequent grades, particularly in math. For instance, being absent for ten days in grade 3 led to a 2% decrease in math test scores, while in grade 5, the effect increased to 8.1%.

Furthermore, researchers at the University of New South Wales investigated the impact of school indoor air quality (IAQ) on academic outcomes.[xxvi] Recognizing that indoor air pollution poses a greater risk to children, who spend a significant amount of time in school environments, the study aimed to understand the implications of exposure to harmful pollutants on human capital accumulation and children's health and development.

Combining detailed information on indoor air quality-related renovation projects with student-level administrative data, the researchers discovered that mold remediation and ventilation improvements had a significant positive effect on test scores. Analyzing data from 74 elementary schools in a Texas school district, where 66 schools had undergone indoor air quality-related renovation projects, the researchers found that mold projects had the most substantial effect on test scores. The average mold project, costing $517,156, was estimated to improve math scores by 0.154 standard deviations and reading scores by 0.139 standard deviations. Mold and ventilation projects with average expenditures significantly increased the probability of passing the reading test by 3.8% and 2.6%, respectively.

Note that diminished attendance has the potential to hinder the learning process by reducing the time available for direct verbal and visual communication of information from teachers and contributing to students falling behind in their coursework.[xxvii] Furthermore, given that school funding is frequently tied to attendance rates, a decline in attendance could lead to reduced financial resources for the school. This, in turn, may compromise the school's capacity to maintain an optimal learning environment, impacting both its physical infrastructure and pedagogical capabilities.

Other studies have indicated that children with higher rates of absenteeism in early kindergarten exhibit lower scores in working memory and cognitive flexibility during early childhood.[xxviii] These effects extend into adolescence, manifesting as lower literacy skills and diminished grade point averages at the age of 15. Moreover, chronic absenteeism during elementary and high school years is correlated with reduced academic achievements in high school, lower rates of high school completion, and a decreased likelihood of graduating from a 4-year college. In essence, students who frequently miss school not only forego teacher-led lessons, peer interactions, and other stimulating activities but also face potential adverse consequences for their overall academic achievement and development.

**HOW WELLSTAT CAN HELP**

In the realm of academic achievement, the significance of the learning environment cannot be overstated. Recent studies highlight the profound impact of indoor air quality (IAQ) on students' health, attendance, and academic performance. Addressing this critical aspect, WellStat IAQ and WellStat energy management system (EMS) present innovative solutions to revolutionize the learning environment and promote student well-being.

WellStat IAQ plays a vital role in mitigating absenteeism by ensuring optimal indoor air quality, reducing the likelihood of students falling ill and missing school. Equipped with advanced sensors, WellStat IAQ actively monitors pollutants, fostering a healthier, more productive atmosphere and combatting Sick Building Syndrome. This technology contributes to a healthier childhood by reducing exposure to harmful pollutants during formative years. WellStat IAQ's real-time monitoring optimizes conditions, enhancing cognitive abilities and creating a conducive environment for learning. Studies indicate a direct link between IAQ and academic performance, and WellStat IAQ, in tandem with WellStat EMS, offers a comprehensive solution by efficiently managing the overall building environment.

*Example of installed WellStat IAQ Wall Mount*

WellStat IAQ and WellStat EMS emerge as holistic solutions for schools prioritizing the health and academic success of their students. Proactively managing indoor air quality and building environments, these technologies contribute to a positive atmosphere that fosters student well-being and academic achievement. As educational institutions recognize the importance of a healthy learning environment, solutions like WellStat IAQ and WellStat EMS stand at the forefront of creating a brighter and healthier future for students.

To learn more about WellStat visit: www.wellstat.io

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