Right under our noses

A simple solution for improving student success

that will work in many low performing North Carolina schools

By Francis P. Koster, Ed. D.

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Many scientific studies have shown that when indoor air quality (IAQ) was improved in a classroom, students' test scores increase by one and in some cases two-letter grades across the entire school.[1,2,3]

Despite the science that shows how improving the physical learning environment positively impacts student performance, only 6 states require that schools be routinely inspected for environmental conditions like poor air quality, mold, radon gas, or lead in the drinking water. North Carolina is not one of them.

The U.S. federal government doesn't have any nationwide requirement, either.[4,5]

This is true for public, private, religious and charter schools.

My name is Francis Koster. I run a Not-For-Profit called The Pollution Detectives that lends simple-to-use electronic equipment to citizens who want to protect their families by 'making the invisible visible'.

One of our focus areas is our nation's K-12 school systems. We lend equipment that monitors indoor air quality in schools for optimal fresh air content, mold, radon, particulate matter, and chemicals. We also lend equipment that surveys school water supplies for lead in the drinking water.

Over the past 18 months, we have identified an amazing opportunity to improve America's educational system.

A true story: Years ago, a friend of mine, quite bright, studious, and determined to make his life's work contribute to a better world, joined several hundred other high school students to take the Scholarship Aptitude Test (The SAT). The test was given in a large school library that normally hosted a mere half-dozen students at a time.

Admission to the college of his choice, scholarships, and his future career trajectory was on the line. He, and a large number of other test takers, became drowsy and/or fell asleep during the 4-hour exam, and their test scores suffered. Because strong performance on the SAT was pivotal to the admission criteria of many schools, my friend and some of his fellow test takers found their dreams altered.

Why did all those ambitious and smart students score poorly on an exam during one of the most important 4-hour periods of their life?

Because the room they took the test in had insufficient supplies of oxygen, and high levels of other ingredients that impair thinking. The library was engineered to bring in fresh air for an average of six occupants per hour every day, and was only used for large scale testing by hundreds of students for a 4-hour event once a year.

And the fresh air replacement part of the building's air conditioning system was not designed to accommodate such a crowd.

The test-taking students did not have enough fresh air pumped into the room for their brains to work.

The problem is not limited to this one example. According to the Environmental Protection Agency, about one-half of all K-12 students attend classes in rooms with poor indoor air quality during the entire school year.[6] This is due in part to old school buildings, which were originally built with windows that opened, but had no ability to bring in fresh air by an air conditioning system. Due to concerns about school security, these windows are now nailed shut.

Our American education system ranks in the bottom half of the world's richest 35 countries,[7] and the most commonly used ranking systems place North Carolina around the middle or below in a list of all 50 states in our country.[8,9,10]

Our state is in the bottom half of the bottom half.

The quality of local schools is a matter of constant political focus, and to fix what appears to be a poorly performing school system, well-intentioned parents and citizens are advocating for a long list of "reforms," including:

- Creation of more public and private charter schools
- Reduced regulation to public schools
- Smaller class sizes
- Reducing the amount of statewide testing
- Increased home schooling and religious-based education

These concerned adults' hearts are in the right place, but their range of solutions misses one of the cheapest and most effective opportunities to improve student learning.

Because there are many kinds of indoor air pollution, there are many scales that are commonly used to manage the ingredients of indoor air. The dominant standard is the number of cubic feet of fresh air brought in per minute per student (called the ventilation rate). The current national recommendation for classroom ventilation is 15 cubic feet per minute (cfm) per child when a new school is constructed.[11] North Carolina, however, only requires half of that.[12] Hence, on top of the large number of old schools with no ventilation, new schools in North Carolina are being built to an obsolete minimum standard that science has shown to be detrimental to children's ability to learn.

One of several ways to survey a classroom to see if the 15-cfm standard is being met is to measure carbon dioxide, or CO_2. The higher the amount of CO_2, the lower the ventilation rate, the slower the brain's functioning, and the less a child learns.

A decades long debate inside the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) led to its recommendation that institutions such as schools maintain levels of CO_2 at or below 1,000 ppm. While ASHRAE's perspective is influential, this lower level has not yet been enacted into law by states.

Take a moment and digest the implications of what you just read: almost half of all of our country's kids spend their school days in existing buildings that no one routinely inspects them for sufficient oxygen, or other threats like Carbon Dioxide (CO2), mold, radon, or chemicals – even though the research shows that creating high quality indoor air reduces illness and considerably increases the learning rate of students. And new buildings are being constructed in a way that will reduce potential learning one letter grade per student per year.

With your help, we can get North Carolina's schools out of the bottom half of the bottom half.

"Your effort is a game changer for American education."

David Mudarri, Ph.D.
Author of ASHRAE's Indoor Air Quality Guide Retired head of EPA Clean Schools program

IMPROVING AIR INSIDE A SCHOOL INCREASES LEARNING

Scientists have now proven that the brain begins to lose the ability to learn or use complex information when oxygen levels in a classroom are low. (A comprehensive bibliography is on our website www.thepollutiondetectives.org)

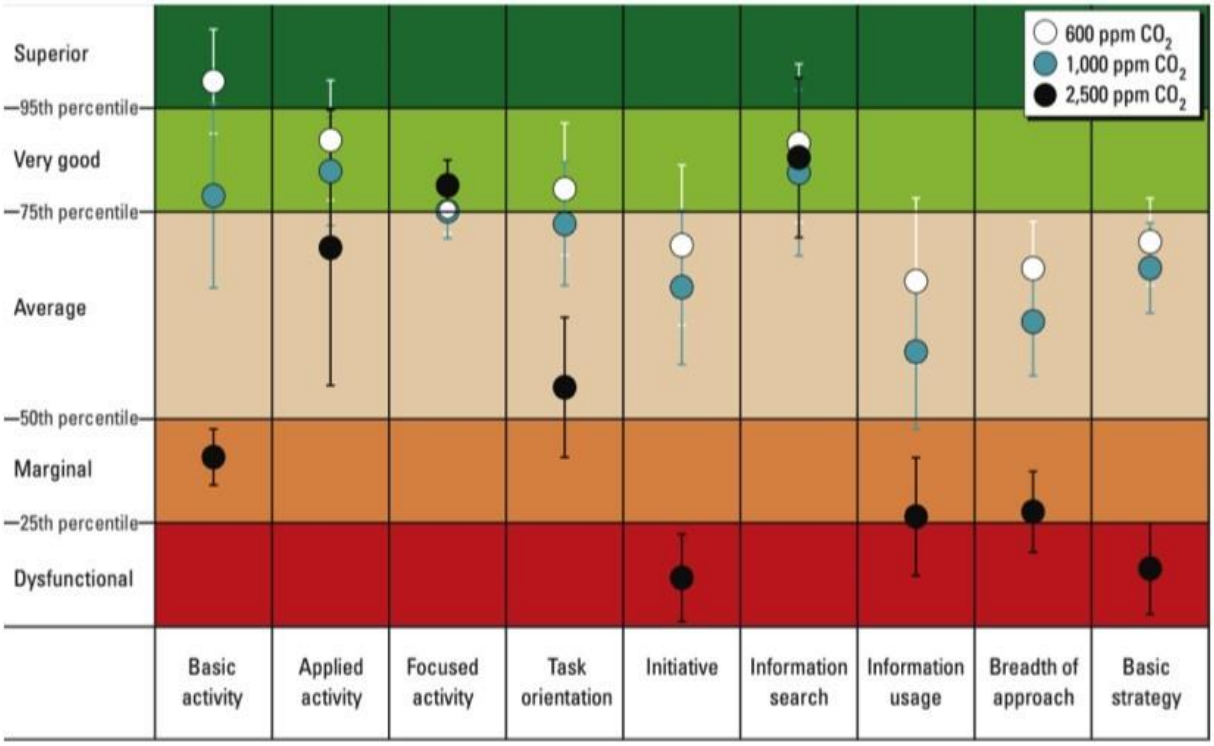
This is how the damage happens: as children breathe in air, they use up some of the oxygen, and exhale Carbon Dioxide (CO_2) and other chemicals into the air. If there is no replacement fresh air, they inhale the old air again, take some more oxygen out of the air, and exhale still more CO_2 and other chemicals. This continues all day long, cumulatively increasing levels of CO_2.

While measuring oxygen levels in a school is challenging, it is easy to measure CO_2 levels as an overall indicator of the quality of the air in the classroom. Think of it like the "check engine" light on your car dashboard - could be any number of issues, but that single light compels you to investigate. The measuring device essentially makes visible a chemical 'sea-saw' – the higher CO_2 levels, the lower the oxygen levels.

Low-cost meters are available that take in air and then count and report on the amount of CO_2 in the room. That amount is expressed as 'Parts Per Million' or PPM, which means that for every million parts of air, some portion is CO_2. At levels above 750 PPM of CO_2 the brain does not work as well as it can.

As oxygen levels go down, CO_2 levels go up. No matter how rich or poor, or how good the teacher or home life is, rising CO_2 in indoor air lowers student learning, and test scores. Our obsolete laws and building code regulations do not recognize this issue - a situation that is hurting our children's, and our countries' future.

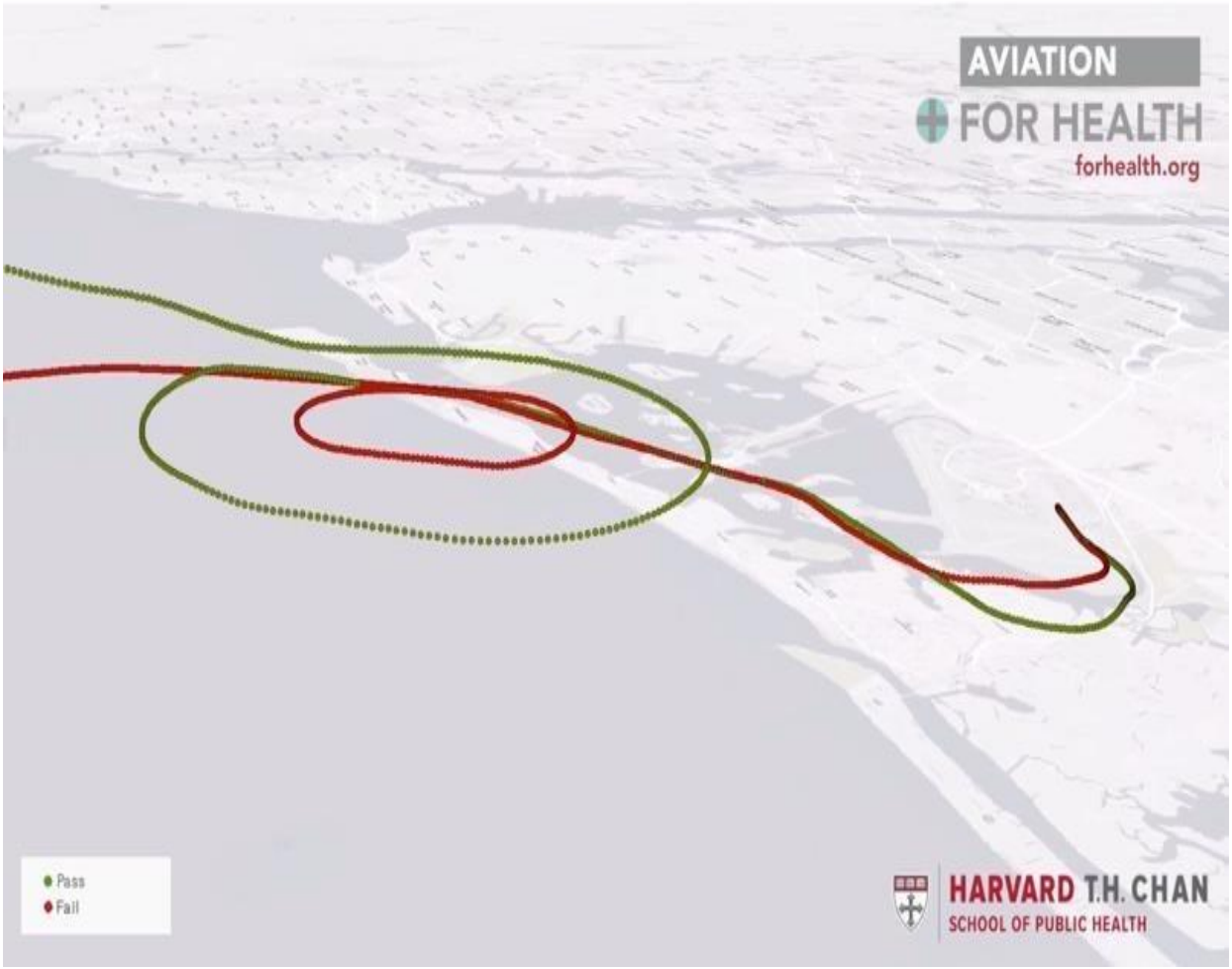
In the following graph, look at how our brains work in 9 different categories of mental activity, under 3 different levels of CO_2 in the air. Notice the dramatic difference in brain function between the white circles at 600 ppm of CO_2 and the black circles at 2,500 ppm of CO_2.



What this graph shows is that the more complicated the mental task is, the more stuffy air slows down the brain. In the case of K-12 schools, the higher grades suffer the largest reduction in learning and successful test taking.

Below are 4 examples (out of dozens available) that illustrate the impact of poor indoor air quality (measured by using CO_2 levels) on learning and information usage.

The first example is about error rates made by airplane pilots. The image below shows how experienced airplane pilots perform at two levels of CO_2 in their cockpit. I start with this example because it is easy to understand.



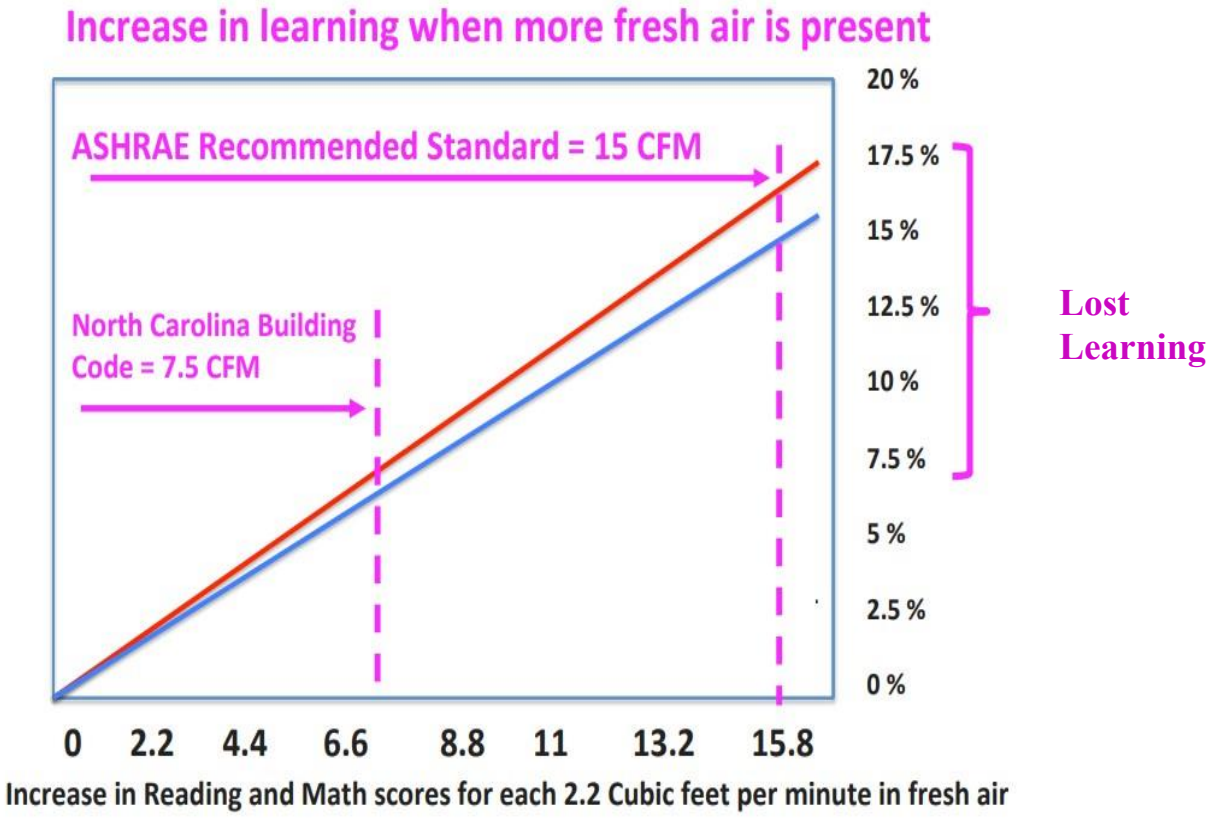
This study, published by Harvard professors in 2018,[13] was performed on experienced pilots using flight simulator trainers. The green (safe) flying pattern was flown when CO_2 inside the cockpit was at 750 PPM. When the scientists manipulated the air quality in a way that raised the CO_2 levels in the simulator up to 2,500 PPM CO_2, the pilot's error rate, shown in red, soared.

Another example is from Texas, where one researcher tracked student performance before and after a string of schools had their air conditioning systems updated. Frank DiNella of the Keller Independent School District is quoted as saying, "After fixing our indoor air quality, we have seen an increase in scores of 17.3 percent on standardized tests."[14] Next is an example from the southwestern U.S., where 100 classrooms were analyzed for indoor air quality issues, and student performance improved in classrooms when problems were fixed. Schools with the worst indoor air quality improved test scores anywhere from 10 to 15 percent, and even schools with the best indoor air quality improved scores by five percent.[15]

The fourth example illustrates how much test performance improves when increased amounts of fresh air are pumped into a classroom.

A minimum of 15 cubic feet per minute per student (which produces CO_2 Levels of around 750 PPM) is considered optimal.[16]

Look at the chart below, which shows how increasing the amount of fresh air in a classroom (the bottom scale, expressed as cubic feet per minute per student) impacts test scores (the vertical scale on the right) raising the scores 17.5% for math, and 15% for English. [17]



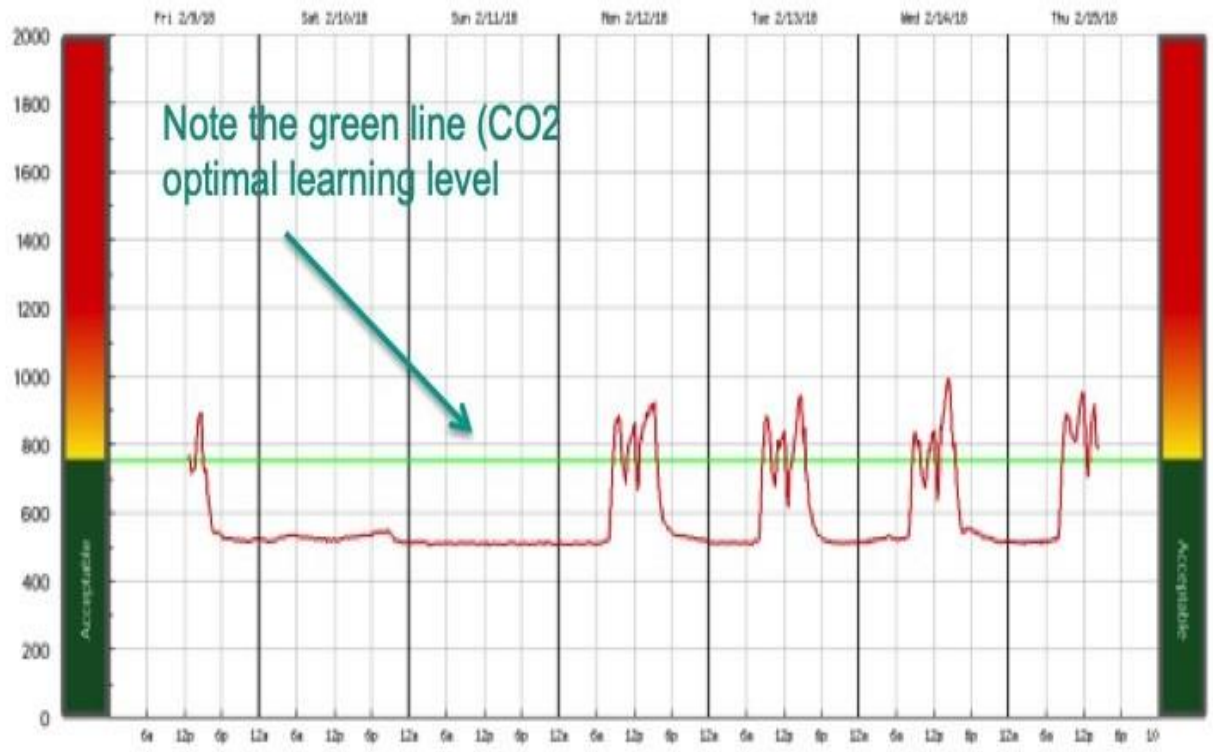
Association between substandard classroom ventilation rates and students' academic achievement
U. Haverinen-Shaughnessy D. J. Moschandreas R. J. Shaughnessy24 August 2010

15 Cubic Feet Per Minute of outside air per minute is a cube roughly the size of your dishwasher. A child breathes in and out about 30 times a minute. If no fresh air is pumped in, the child continues to repeatedly inhale the oxygen-reduced air, removing still more oxygen with each breath. After a little while, as CO_2 levels grow, mental functioning, particularly for complex tasks, is reduced.

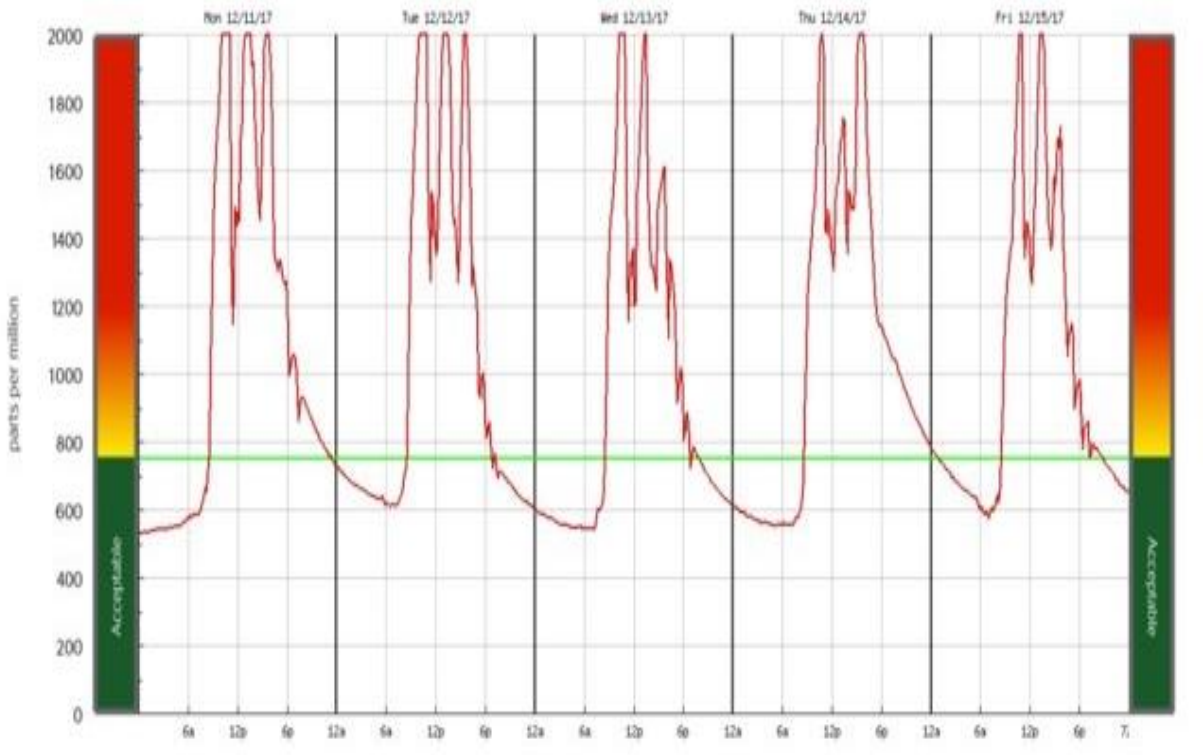
Below you can see some indoor air quality graphs. Keep in mind that students learn best when CO_2 levels are 750 PPM. The graphs were developed from information gathered by monitors placed in three schools in western North Carolina.

Note the green line, which indicates the optimal level of 750 PPM in all three graphs. Then, note the peak of the daily readings (in red), which is at 2,000 PPM in two of the three examples. As the third chart shows most clearly, when CO_2 levels reach 2,000 PPM or greater for a period of time, the top of the red peak is flat. This occurs because our monitors are calibrated to maintain a high degree of accuracy across a range from zero (0) to 2,000 PPM. As measurements of CO_2 rise beyond the maximum value, the monitor continues to report a reading of 2000 PPM. Therefore, when the top of the red peak is flat, CO_2 levels most likely exceed 2,000 PPM.

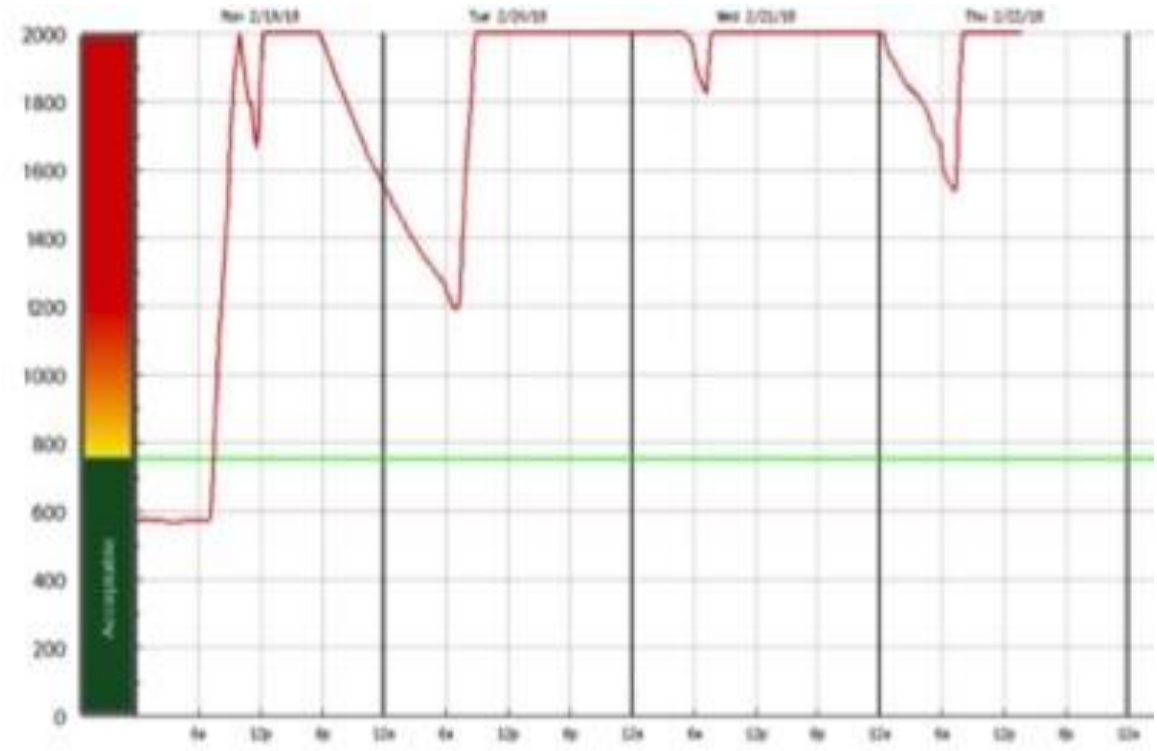
This first example is what we would hope CO_2 levels would be in every classroom:



However, about half of all K-12 classrooms we have surveyed have meter readings approaching or over 2,000 PPM during some portion of the school day. The second example, below, is consistent with about 40 percent of all classrooms we assisted the school districts in surveying. Students in the following classroom will be deprived of about one letter grade of learning per year—particularly if curriculum is taught at the middle-school level or higher.



Some classrooms are so bad it is amazing that any learning occurs at all. Students taught in these classrooms through multiple grades—about 10 percent of all those enrolled—will miss out on two letter grades of learning each consecutive year. The cumulative deficit will preclude many lifetime opportunities, including any hopes for a college scholarship.



Another way to quantify the opportunity to improve our schools: track absence rates

Another window through which to see the opportunity to improve schools is the number of student sick days. Although few school systems measure CO_2 in their classrooms, almost all measure student absenteeism.

Schools with high numbers of student sick days usually lack enough fresh air. One of the earliest studies of this is from Sweden, where researchers took a look at a large daycare center that was housed in an old building.

Before they made any improvements to the building, they measured student sick days over a one-year period. Before the start of the second school year, they installed modern air cleaning equipment and proper ventilation and recorded student sick days during this second year. At the end of the second year, they removed the air cleaning equipment and went back to the old system, and then counted student sick days for that third year.

During the first year, the absenteeism rate was 8.31 percent. In the second year, with the air cleaning equipment in place, it dropped to 3.75 percent. And in the third year, after the air cleaning equipment was removed, it rose to 7.94 percent. [18]

Other nations, including the United States, were impressed and tried similar efforts.

Connecticut is a good example, where a program was instituted to fix indoor air quality issues in its schools. The before and after numbers are stunning:

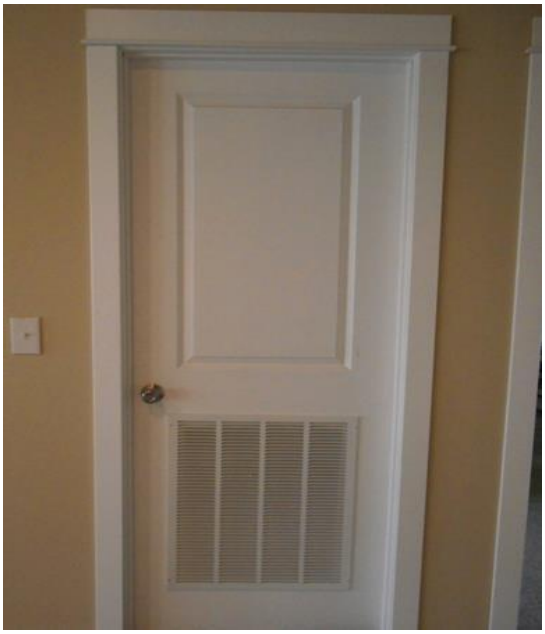
- After upgrading its air conditioning system, the City of Hamden saw one school cut its sick days from 484 to 203 in one year, and the school nurses reported a large drop in the use of student inhalers
- A North Haven school had a drop of 48% in respiratory-related Illnesses
- The city of Waterford had a 66% decrease in air-quality-related health complaints in nine out of 13 elementary schools[19]

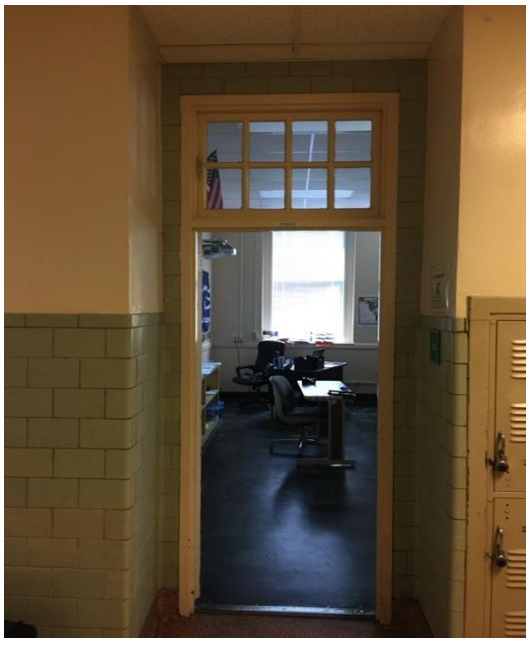
How school building age factors into this opportunity

Many communities have beloved old school buildings that contain precious memories. Suggestions that they be torn down and replaced with newer buildings can create a lot of tension, and angry PTA meetings. Most of those angry meeting attendees do not know that continued use of these buildings without modifying them can actually hurt their children's future.

Back in the day, most kids walked or rode bicycles to school, had recess outside, took some portion of their lunchtime outside, and walked or rode their bicycle home. They got to breath a lot of fresh air. If their school got stuffy, the teacher could open the windows, or open a transom window over the classroom door so fresh air could blow through. On a daily basis, outside the classroom, the kids got a lot of fresh air. Inside the classroom, the only thing the building's heating and cooling hardware could do was pump hot or cold air or water around the building to control the temperature - not the amount of fresh air.

Schools built in this style brought fresh air into the classroom by opening exterior windows, air vents in interior doors, and transom windows over the hallway doors (shown below).





These ways to increase fresh air in the classroom have been disabled in most older schools because efforts to reduce energy costs resulted in windows and transom vents being nailed and caulked shut, and the door vents to the hallway being sealed with plywood to control noise from the hallway.

Now the kids in older schools breath the same classroom air in and out all day long, except when the hallway door is open - something that does not happen very much.

In the 'middle aged' schools, many of the windows were never operable, and their older HVAC ventilation systems which were supposed to bring in fresh air have lost a lot of this capability. Additionally, national studies (and our own work) show that those ventilation systems are often broken, disabled, or are never turned on in the first place to reduce energy bills.

The average age of school buildings in the U.S. is 44 years.[20] This means that half our nations' schools are older than that, and almost certainly have obsolete or worn-out systems for bringing in fresh air.

Once a school is built, there is no legal obligation to bring those buildings up to more modern air quality standards. And all of the students attending those treasured decades old schools are suffering lifelong missed opportunity for economic and social mobility.

We find the same performance situation in some locations where the students are in new buildings with sophisticated computerized systems, but the maintenance staff (many of whom have been working in the district for decades) do not know how to operate the equipment, and often set them at the simplest settings – causing them to function very much like the ancient systems that were replaced. Very little auditing is done to make sure their systems are operating as designed.

According to a massive survey by the U.S. Environmental Protection Agency, one half of the nation's 115,000 K-12 schools have indoor air quality problems.[21]

One interesting dimension of this problem in North Carolina is that support for school system personnel is derived from state and local taxes, and distributed to schools on a per capita enrollment basis. There is equality of funding for instruction. On the other hand, the physical plant of the schools is the responsibility of the local political jurisdictions where the schools exist. This means that students from a wealthy school district can have vastly better school buildings than their poor cousins in an older, often rural or poor urban school district.

This is likely to result in economically disadvantaged school districts showing lower student success rates, which is often blamed on poor parenting, when it is far more likely to be due to indoor air quality.

SEIZING THE OPPORTUNITY TO IMPROVE OUR EDUCATIONAL SYSTEM AND OUR KIDS' HEALTH

There are three major areas to be mastered when seeking to address these issues:

The first thing to be understood is that in most parts of the United States, the law calls for new buildings to be designed and built to provide 5,000 PPM of CO2 to occupants. This standard, initially proposed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), was developed many years ago before the impact of CO2 on the brain was understood – and it still stands.[22] The Occupational Safety and Health Administration (OSHA) still maintains this exposure limit for an eight-hour workday.[23] Today, ASHRAE does have a "recommendation" that office buildings and classrooms with younger students be operated at 1,000 PPM CO2.[24] However, it has no legal force behind it, and is often ignored. According to North Carolina's Department of Environmental Quality, the state defers to ASHRAE's suggested level of CO2 but refrains from pronouncing a legally-binding limit.[25]

The second step that needs to be taken is to **educate the school systems, teachers and parents about the impact that poor indoor air quality has on student performance.**

Very few educators have had any training in the science linking indoor air quality and brain function, and most importantly, the vast majority of the maintenance technicians who maintain school air conditioning systems have never heard of this research.

Almost no one in America's K-12 educational system knows that fixing indoor air quality can lower student absence rates by half, reduce teacher sick days by the same amount, raise standardized test scores between 5 and 17 percent. and that more scholarships will be received due to better scores on standardized pre-college tests.

An irony associated with this issue is that school leadership has been criticizing the teachers for student's failure, when in fact a good portion of the problem may be caused by that same school leadership encouraging facilities managers to save money by reducing fresh air intake.

Fixing this unrecognized issue will require a cultural shift to occur both at the leadership level, and the building maintenance staff level…something that studies of culture change and adoption of innovations indicate can take decades unless efforts are made to introduce all parties to the literature by aggressive systemic training.

Additionally, colleges and universities who train future educators should be encouraged to share this information with the population that will become the education system leaders of tomorrow.

The third step that needs to be taken is that industry has to demonstrate to school system leadership that the solutions are easier to implement than they think.

In our United States, school superintendents seem to serve in their positions for only a short amount of time - 3 years for school systems with large numbers of low-income students or students of color, to 6 years for superintendents of large urban school systems with a high percentage of affluent students.[26]

For a Superintendent to keep their job requires endless balancing of multiple interest groups, including taxpayers, parents (with many subgroups) and students (with many sub-groups). To protect job security, public conflict is often avoided at all costs.

Time after time we have heard from school officials who say that they are trapped – that they have no money to make expensive desired changes, and if parents were to become aware of the problems, community morale and the school system's reputation would suffer, and the emerging flight from public schools would accelerate. (It should be noted that our research indicates that there is no guarantee that the schools they are moving to have any better classroom air quality.)

School leadership can choose to remain ignorant of the problems, or learn about them while hiding their magnitude, or reveal them and suffer a wave of criticism and risk being fired. Not a good set of choices.

A commonly held belief of school administrators is that if specific repairs or improvements are undertaken in an older building, then the entire structure will have to be brought up to current building code - construction of ramps for the handicapped, new exterior doorways to comply with the latest safety codes, or installation of new levels of fireproof doors or windows.

While it is accurate that some building improvements can trigger such a requirement, according to the head of the North Carolina Building Code Division it is often not true in the case of either repairing or modifying an existing air conditioning system.[27]

If school leadership understood this, they would realize that the cost of improving their standardized test scores one or two letter grades is far lower than they had believed. Additionally, funding may be available.

Not all efforts to improve indoor air quality cost money:

- Some school systems have enlisted parents with appropriate experience in the building trades to donate time to a "Fix Our Schools" project. The older kids and their parents can test the air with new modern monitors (which we will lend out for free), inspect schools for clogged filters, and repair windows and doors so fresh air can enter the classroom.

- Improvements could be paid for by parents, as in the example of Public School 87 and Public School 6 in New York City, where the PTA raised enough money to upgrade all the air conditioning in their kids' schools.[28] Such a parent campaign need not cover the full cost - parents' donations could be pooled and used to coax the city, county or local charitable foundations to match funds and contribute.

- If the needed improvements require significant investment, the cost of installing more energy efficient equipment is usually recouped in 5 to 10 years due to the reduction in energy bills, less substitute teacher workday expenditures, and less money spent for employee healthcare. This is

equivalent to a 10 to 20 percent rate of return on investment, which can be persuasive to both civil servants and private investors, especially when municipal bond interest is often one-half that amount.

In addition to charitable donations, there are at least three ways to raise the capital for this investment:

(1) Taxpayers can re-prioritize existing budgets, or lobby for a bond issue to finance the projects. Mobilizing the electorate would require sustained education and publicity about the opportunity, but this can have a positive ripple effect on the entire community.

(2) The school system can look to private investors. In the case of school buildings with obsolete or worn-out air equipment, private investors are often interested in investing in the more modern and efficient equipment and installing it in exchange for sharing the economic benefits of reducing energy costs and reduction in the costs of substitute teachers who are hired when full time staff have to take a sick day. In North Carolina there are more than a dozen companies eager to do this. They are called Energy Service Companies (ESCOs) - see our website for a list. And there are private companies who can benefit from government tax incentives not available to public property owners for investments made in low-income areas – the very areas where older school buildings often exist. After obtaining the tax advantages, the school system buys the equipment from the investor several years down the road using the money saved by reducing energy costs. Both parties make money.

(3) This option is about to become better known with publication of regulations governing Opportunity Zones, a portion of the 2017 tax reform package that grants significant tax reductions to private investors who put their money to work in impoverished areas.[29] These tax advantages can be stacked on top of other better-known tax incentives.

Conclusion: North Carolina, and many other states, can significantly improve the performance of their school systems by taking advantage of a rapidly growing body of scientific knowledge about the impact of poor air quality on the brain. Some of the solutions can be undertaken by maintenance staff and parents, while

some will require raising money through various forms of political action like bond issues, or financed by private investment.

In all cases the rate of return in financial terms is quite impressive. And any solutions currently on the table do not adequately address the impact on student learning. Seizing this opportunity will be a huge step to improve social mobility for decades to come.

In all cases courage will be required of school administrators in order to acknowledge the issue, and provide leadership. The key question to be answered is "will future directions be driven by the desire to protect the school system leadership, or the children."

# # #

About the author

Francis Koster, Ed. D. is a "retired" pediatric healthcare administrator with a passion for helping children maximize their potential. In an effort to "make the invisible visible," he has created a not-for-profit organization that lends equipment to students, faculty, staff and parents to use for measuring and reporting on school's indoor air quality, lead in school drinking water, and radon gas, to create opportunities to improve performance in schools.

You may request to borrow a monitor for testing your child's school by emailing info@thepollutiondetectives.org.

To learn more about our program, see www.thepollutiondetectives.org.

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