

# Schools and the Indoor Environment

Idaho Energy and Green Building Conference

November 2, 2016

# Overview

- ▶ People spend on average close to 90% of their time indoors
- ▶ Therefore the quality of the indoor environment matters for health and productivity
- ▶ Increasing the ventilation rate significantly lowers the concentration of indoor generated contaminant.
- ▶ Children go to school 7 hours a day 5 days a week
- ▶ Most of that time is spent in the classroom

# Children's Health

- ▶ Children are not mini adults
- ▶ They have a higher respiration rate: 30 - 60 breaths/min compared to 12-20 for adults
- ▶ They consume more contaminants relative to their body size

**“Smaller lungs mean a relatively higher surface area to volume ratio, such that children are already absorbing a greater volume of contaminants relative to their body size compared to adults. Also, a child’s breathing rate is faster than that of an adult, so every minute they exchange more air per kilogram of body weight. Being smaller in size, a child’s breathing zone is much lower than that of an adult. Some heavier contaminants, such as pesticides or automobile exhausts, are typically present in a vertical gradient, being in higher concentration closer to the ground, therefore closer to the child’s breathing zone.”**



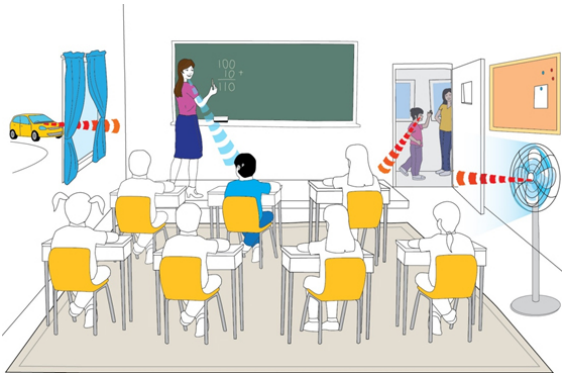
Source: <http://www.apzem.com/india/products/indoor-air-pollution-control.html>

# Notes on Background Noise

The ability to recognize speech in the presence of background noise isn't fully developed until the teenage years.

One study found a substantial decrease in children's abilities to execute complex oral instructions in classroom environments due to the effects of background noise.

Cognitive functions in children are vulnerable to the negative effects of environmental noise because they are less developed and more prone to disruption.



Source:  
<http://www.cochlear.com/wps/wcm/connect/in/home/support/excel-at-school/the-importance-of-technology>




Source:  
<http://www.additudemag.com/adhd/article/731.html>

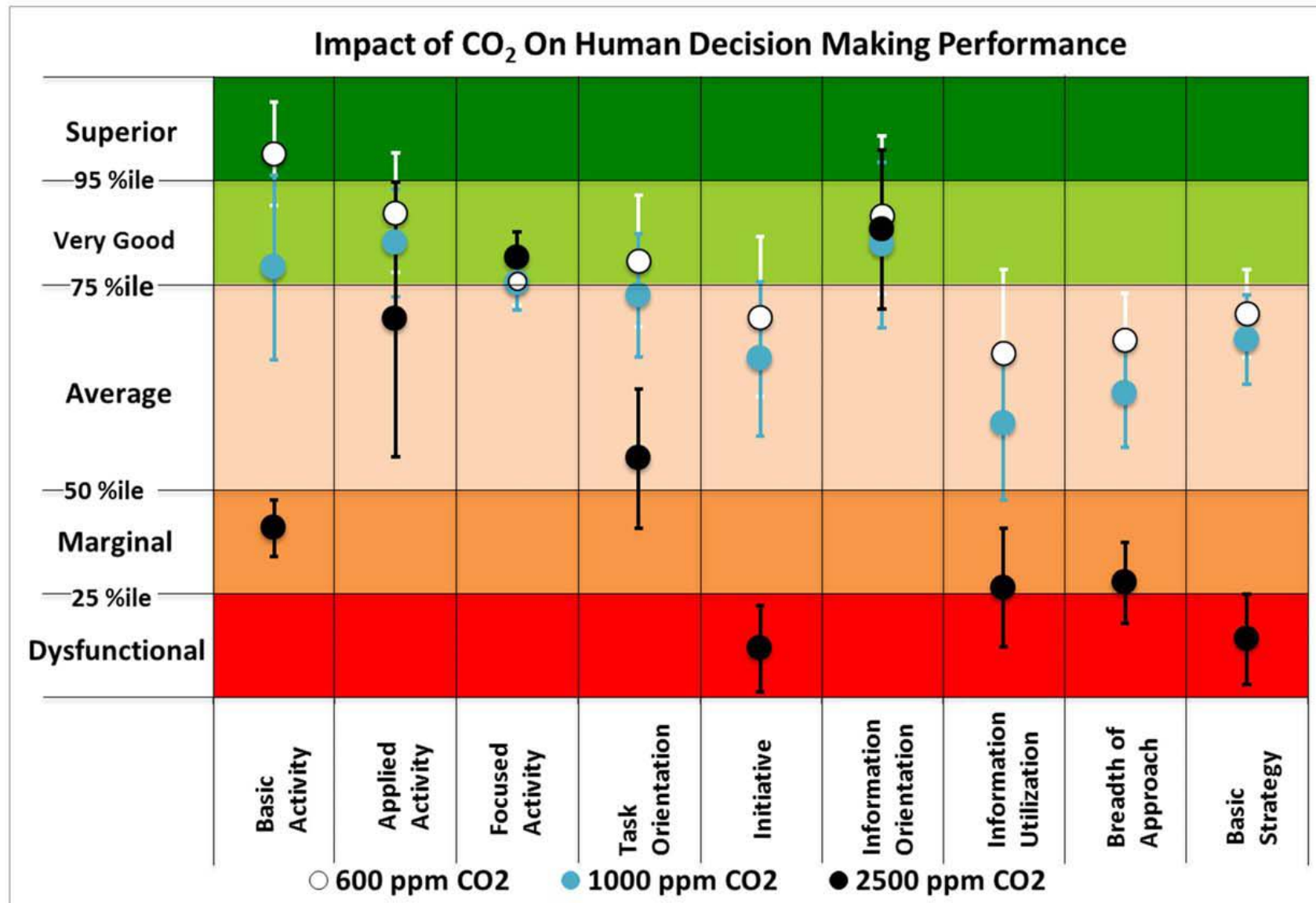


Source:  
[http://www.phonicear.com/SF/Sound\\_learning\\_environment/Distance\\_background\\_noise\\_reverberation.aspx](http://www.phonicear.com/SF/Sound_learning_environment/Distance_background_noise_reverberation.aspx)

- ▶ Visual cues
- ▶ Previous knowledge of the topic
- ▶ Mental ability to fill in the blank

- 
- ▶ The Health Impact of CO<sub>2</sub>
  - ▶ Increased Student Performance
  - ▶ Financial and Other Benefits

Ventilation rates that meet the minimum standards correspond to CO<sub>2</sub> concentrations above 1000 ppm for densely populated spaces such as classrooms



Source: Satish, U., Mendell, M. J., Shekhar, K., Hotchi, T., Sullivan, D., Streufert, S., & Fisk, W. J. (2012). Is CO<sub>2</sub> an indoor pollutant? Direct effects of low-to-moderate CO<sub>2</sub> concentrations on human decision-making performance. *Environmental health perspectives*, 120(12), 1671.

# Increased Student Performance

It has been proposed that doubling the outdoor air supply rate would improve the performance of schoolwork in terms of speed by about 8%

In classrooms with low rates of ventilation students are likely to concentrate less and be less attentive to the teacher's instructions.

Students in classrooms with improved air quality experience improved health



Source: <http://www.shescribes.com/2012/12/raise-that-hand-oxfordlearning.html>



Source: <http://atlantablackstar.com/2015/09/18/new-study-shows-teacher-diversity-public-schools-crisis/>



# Increased Student Performance

Research carried out in ASHRAE 1257 - TRP proposed that each doubling of the outdoor air supply rate in a classroom would result in an **increase of 14.5% in the performance of schoolwork.**

Research carried out in ASHRAE 1257 - TRP found that each reduction of classroom air temperature by 1°C (1.8°F) during warm weather resulted in an **increase of 2% in the performance of schoolwork.**



Source: <http://go.sdsu.edu/education/ncust/partnerships.aspx>

# Financial and Other Benefits

A study of student absence due to illness in California elementary schools concluded that increasing ventilation rates would decrease student absences by 3.4%. This would increase attendance-linked funding to schools by \$33 million annually at an increased cost of only \$4 million.

Green schools exhibit a 17% reduction in absenteeism, 24% of students perform much better, and these schools have a 20% higher ability to attract and retain teachers.

In a 2006 survey the average cost premium for 30 green schools in 10 states nationally was 1.65 percent, which translates into a cost premium of \$3-4 per square foot. The study results showed an energy savings of 33 percent and a water savings of 32 percent. Overall, the study found a benefit-to-cost ratio of 20 to 1 in green schools.

# Financial and Other Benefits

Increased teacher productivity  
increased average daily attendance

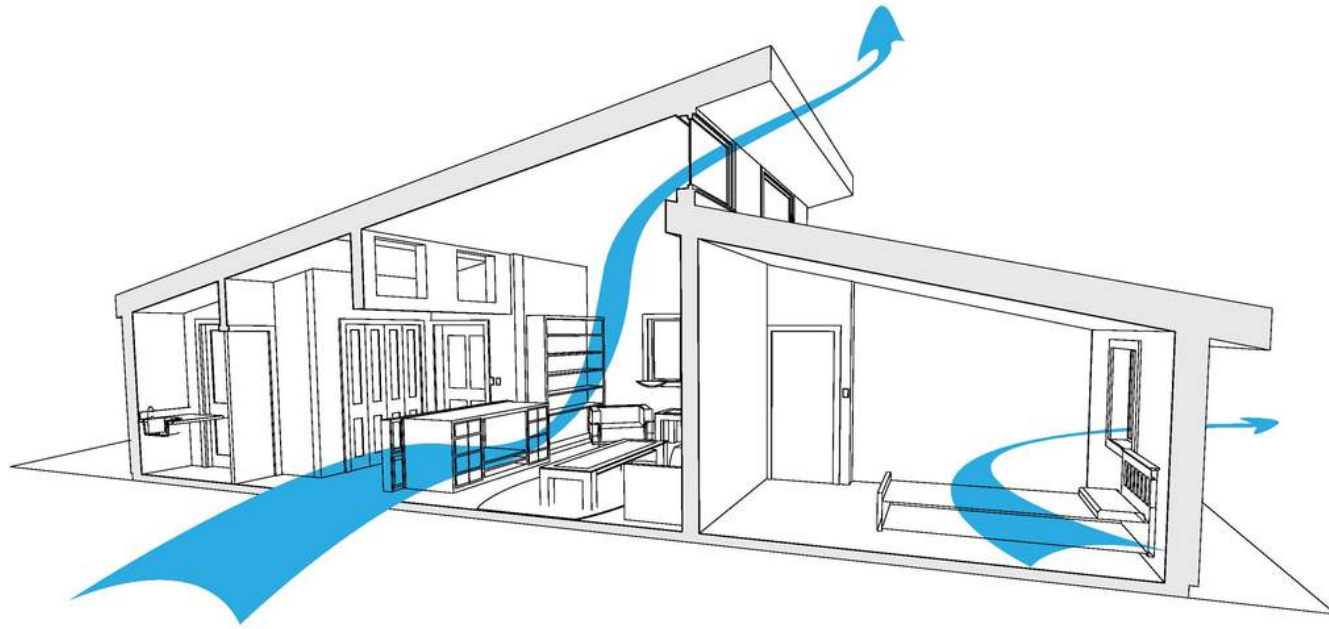


Financial Benefits of Green Schools (\$/ft <sup>2</sup> )	
Energy	\$9
Emissions	\$1
Water and Wastewater	\$1
Increased Earnings	\$49
Asthma Reduction	\$3
Cold and Flu Reduction	\$5
Teacher Retention	\$4
Employment Impact	\$2
<b>Total</b>	<b>\$74</b>
Cost of Greening	(\$3)
<b>Net Financial Benefits</b>	<b>\$71</b>

Source: Kats, G. 2006. Greening America's schools costs and benefits. Capitol-E.com. Washington, DC: Capitol E Publications

# Natural Ventilation

- ▶ Brings in outside air
- ▶ Quieter
- ▶ Limitations
- ▶ Occupant error



Source: <http://southernathena.com/natural-ventilation-tricks-to-cool-off-your-summer/>

Implementing a simple ventilation protocol based on a cross and single-sided ventilation strategy in occupied classrooms can result in a significant decrease in the CO<sub>2</sub> concentration without modifying the comfort conditions.

Windows are opened more frequently before classes, during breaks and at the end of classes, rarely during them mainly because of exterior noise and specific difficulties with opening systems.

When classrooms are warm, windows and doors are operated in such a way as to decrease classroom air temperature. **When the outdoor air supply rate is reduced windows and doors are not opened.** This suggests that natural ventilation solutions cannot rely on occupant initiative alone.



Source: <http://quotesgram.com/open-and-closed-doors-quotes/>

# A Potential Tradeoff

## Increased Ventilation Rates

- ▶ Lower levels of indoor contaminants
- ▶ Healthier students
- ▶ Higher student and teacher performance

## A More Well Sealed Building

- ▶ Lower energy costs
- ▶ Greater thermal control
- ▶ Blocking outside noise

# The Takeaways

- ▶ When designing a school the classroom is the most important space to design
- ▶ When designing the classroom you need to think about ventilation, ventilation, ventilation
- ▶ The best solution will be a mix of natural ventilation and a down-sized efficient mechanical system
- ▶ To get this right it will take an integrated design approach
- ▶ The entire design team needs to meet early and often



“Educating children is one of the most important ways of benefiting future generations, so we should not allow energy and resource conservation measures to result in classroom conditions that reduce children’s ability to perform schoolwork. Any proposed changes in the design and operation of school classrooms that are made in the name of sustainability must therefore improve classroom conditions before attempting to save energy.”



# References

Bakó-Biró, Z., Clements-Croome, D. J., Kochhar, N., Awbi, H. B., & Williams, M. J. (2012). Ventilation rates in schools and pupils' performance. *Building and Environment*, 48, 215-223.

Choi, S., Guerin, D. A., Kim, H. Y., Brigham, J. K., & Bauer, T. (2014). Indoor environmental quality of classrooms and student outcomes: a path analysis approach. *Journal of Learning Spaces*, 2(2).

Den Wymelenberg, Kevin. "Why Daylight" 2009 Presentation.

Dutton, S. M., & Fisk, W. J. (2015). Energy and IAQ Implications of Alternative Minimum Ventilation Rates in California Retail and School Buildings.

Green Schools: Attributes for Health and Learning. The National Academic Press. Washington D.C. 2007

Jaramillo, A. M. (2013). The link between HVAC type and student achievement.

Kats, G. 2006. Greening America's schools costs and benefits. Capitol-E.com. Washington, DC: Capitol E Publications

Klatte, M., Bergstrom, K., Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children.

Mendell, M. J., Eliseeva, E. A., Davies, M. M., Spears, M., Lobscheid, A., Fisk, W. J., & Apte, M. G. (2013). Association of classroom ventilation with reduced illness absence: a prospective study in California elementary schools. *Indoor air*, 23(6), 515-528.

Pinto, M., Almeida, R., Pinho, P., Lemos, L., & Lanzinha, J. (2014, December). Experimental assessment of IAQ improvement in naturally ventilated educational buildings. In 40th IAHS World Congress on Housing. IAHS.

Respiratory Health Effects. (2000). Retrieved October 14, 2016, from <http://www.cape.ca/children/resp1.html>

Satish, U., Mendell, M. J., Shekhar, K., Hotchi, T., Sullivan, D., Streufert, S., & Fisk, W. J. (2012). Is CO2 an indoor pollutant? Direct effects of low-to-moderate CO2 concentrations on human decision-making performance. *Environmental health perspectives*, 120(12), 1671.

Turner Construction Company 2005 Survey of Green Buildings

Wargocki, P., & Wyon, D. P. (2013). Providing better thermal and air quality conditions in school classrooms would be cost-effective. *Building and Environment*, 59, 581-589.

Wheeler, Andrea (2014) "The Sustainable School: Effective and Energy Efficient Ventilation in the Classroom, and the Question of Educational Performance and Wellbeing" World Sustainable Building Conference, 28th - 30th October, Barcelona.