



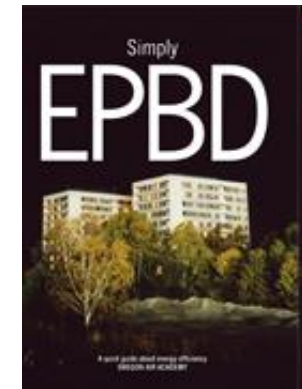
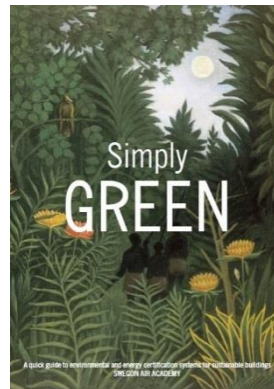
Uticaj temperature i kvaliteta vazduha na  
rezultate rada đaka u školama

Thermal and air quality effects on the  
performance of the schoolwork by children

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# What is Swegon Air Academy?

- Exchange the knowledge
- Seminars
- Paper articles
- Literature



SAA, spreading knowledge about our indoor environment so we might make better decisions as HVAC professionals.

# Thermal and air quality effects on the performance of schoolwork by children

The work and presentation material of David Wyon and Pavel Wargocki.

[www.ie.dtu.dk](http://www.ie.dtu.dk)

How many hours of schooling?

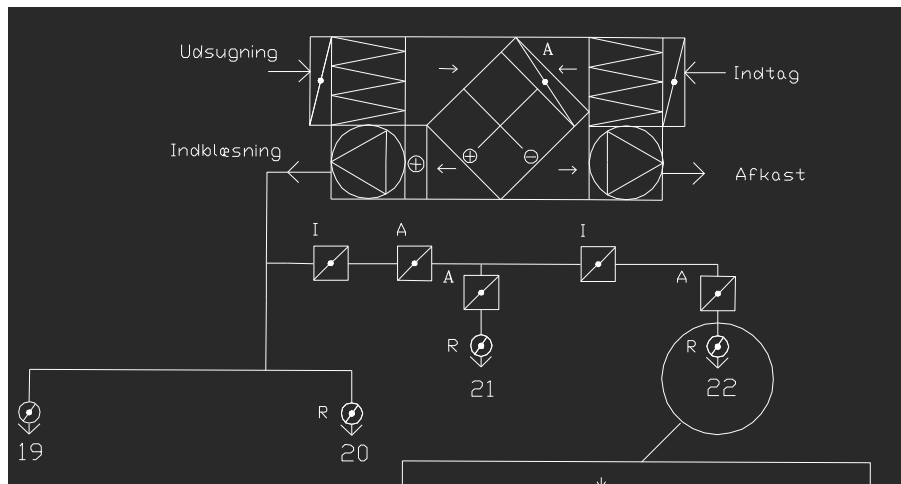
# Field intervention experiments by DTU under ASHRAE 1257:

To determine whether improving classroom air quality and ensuring classrooms do not become warm can improve the performance of schoolwork by children.

Window opening behaviour was passively recorded during the experiments.

# Method: Ventilation

- Indoor air quality was modified by increasing the outdoor air supply rate from an existing mechanical ventilation system



# Method: Temp control and filtration

- Air temperature was reduced in hot weather by installing & operating split cooling units

## Split cooling



## Electrostatic air cleaners



# Method: windows and doors

- Windows could be opened as usual.
- Window opening behavior was recorded as "All windows closed" or "1 or more open".
- Door opening was also recorded.

# Physical measurements

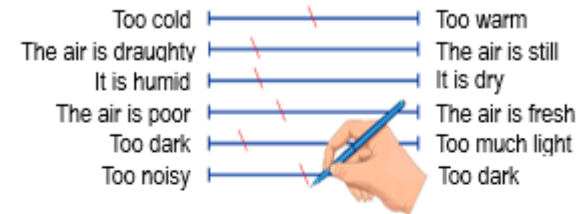
- Continuous measurements (with pupils): CO<sub>2</sub>, Air T, RH, window opening state recorders.
- Effective outdoor air supply rate in L/sp was estimated from CO<sub>2</sub> rate of increase each time children entered the classroom. Note that this includes air entering through windows or doors as well as supply air from the ventilation system.



# Measurements of perceptions and symptoms

- The children marked Visual-Analogue scales at the end of the week.
- They reported the:
  - Classroom environment.
  - Intensity of the symptoms they experienced.

## How is the classroom right now?



## How do I feel right now?

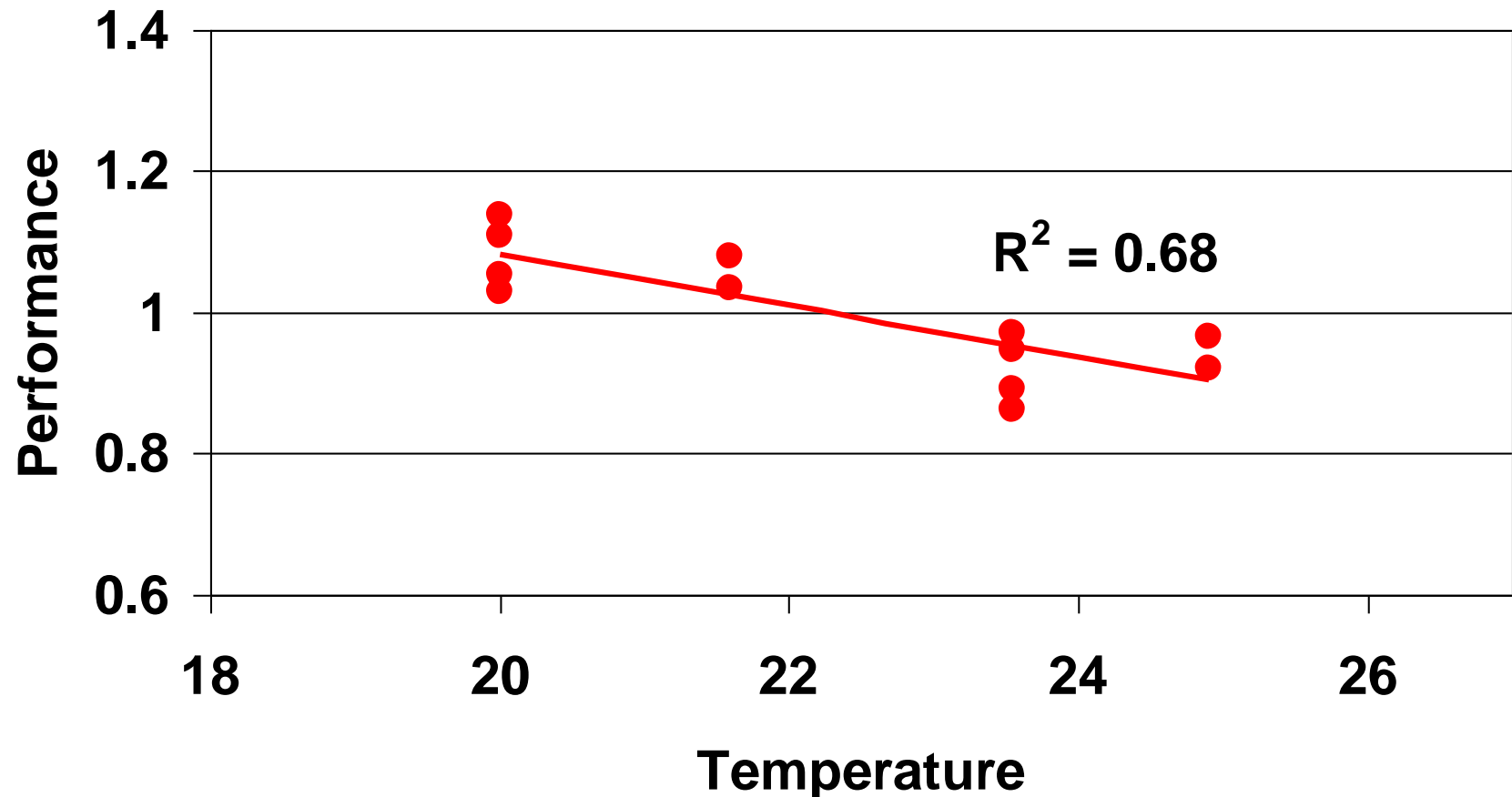


# Measurements of performance

- Tasks appropriate to children's age were developed in consultation with class teachers
- 4 language-based:
  - Acoustic proof-reading
  - Reading and comprehension
  - Logical reasoning
  - Proof-reading
- 4 numerical:
  - Subtraction
  - Multiplication
  - Number comparison
  - Addition

Tasks were performed in mathematics or language lessons.

# Performance of schoolwork as a function of classroom temperature



1°C lower temperature ~3.5% higher performance

# Earlier experiments by DP Wyon in Sweden in 1967

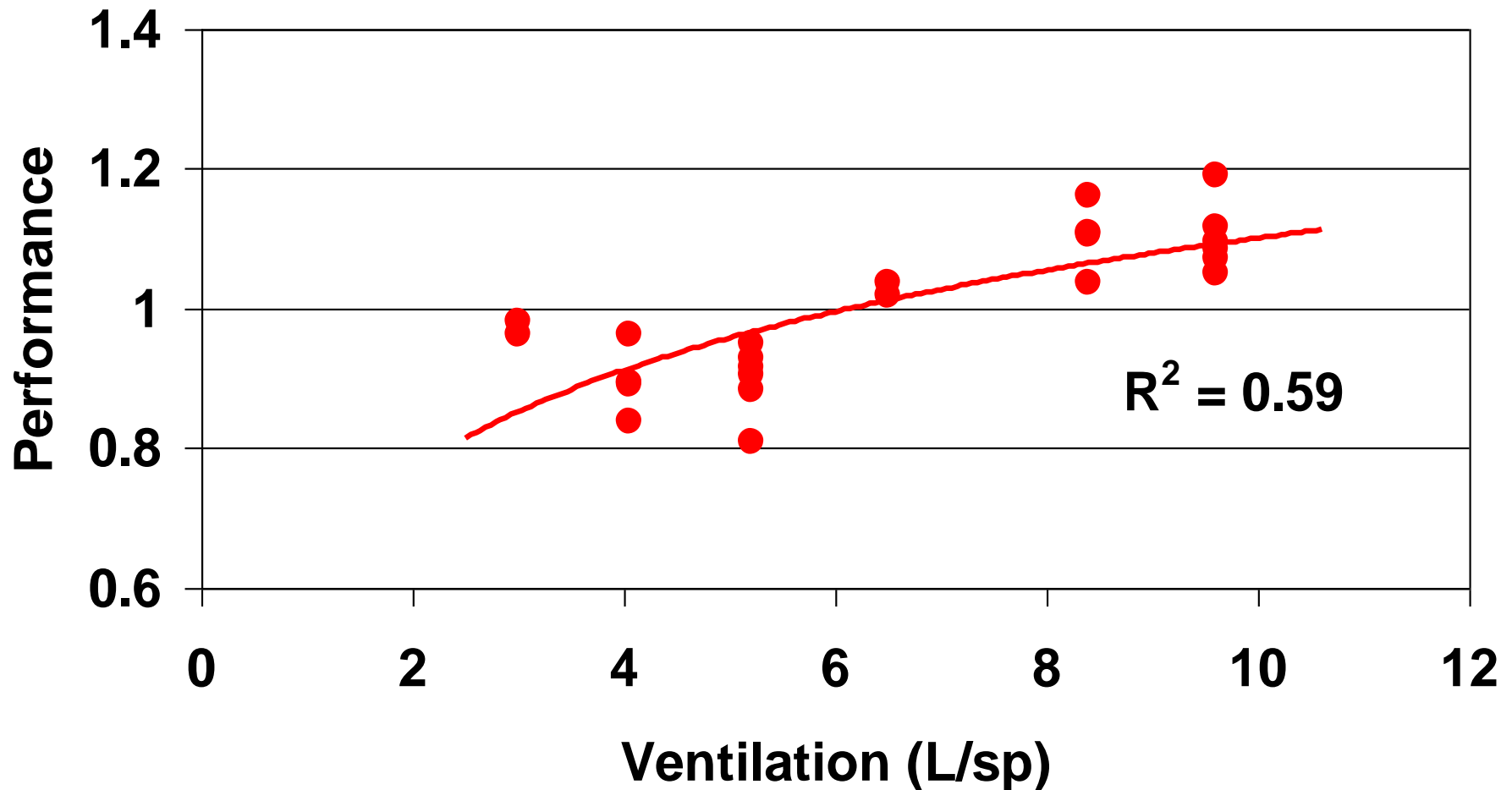
- Raising classroom temperature from 20°C to 30°C reduced most types of schoolwork performance by up to 30%.
- For 40 years this was widely believed to be an overestimate.
- The present results confirm the size of the thermal effect first reported in 1967: +10°C would lead to 35% less schoolwork.

# Increased outdoor air supply rate

Three independent field intervention experiments with 100% outdoor air supplied through new filters:

1. 3.4 was increased to 9.5 L/sp
  2. 3.0 was increased to 6.5 L/sp
  3. 5.0 was increased to 9.5 L/sp
- (with and without cooling)

# Performance of schoolwork as a function of classroom ventilation



Doubling ventilation rate  $\sim 14.5\%$  higher performance

# Classroom air quality matters

- Windows are often not opened.
- Outdoor air supply rates are often low.
- CO<sub>2</sub> levels are often above 1000 ppm.
- Increasing the air supply rate from 2.5 to 5 to 10 L/sp – would improve the performance of schoolwork by 29%.
- Poor air quality is a major disadvantage for children, and especially for slow workers.

# CO<sub>2</sub> in 1663 Scandinavian classrooms – October 2009

Table 3. The percentage of classes exposed to CO<sub>2</sub> concentrations above the recommended limits 1000 ppm, 1200 ppm and 2000 ppm in Denmark, Sweden and Norway for the three types of ventilation.

		Classes exposed to CO <sub>2</sub> concentrations above the recommendations [%]		
		Natural	Exhaust	Balanced
Denmark	1000 ppm	69	51	37
	1200 ppm	64	43	26
	2000 ppm	30	16	3
Sweden	1000 ppm	47	38	12
	1200 ppm	33	31	6
	2000 ppm	7	13	1
Norway	1000 ppm	48	30	10
	1200 ppm	44	17	8
	2000 ppm	7	13	2



## Main 1257-RP conclusions

- Reducing even slightly warm classroom temperatures eliminated thermal discomfort and improved children's performance.
- Increasing outdoor air supply rate improved classroom air quality and children's performance.
- Schoolwork was performed faster, with no increase in errors, in both cases.

# Implications

- Removing airborne particles had no effect, so the IAQ effects were due to gas-phase pollutants in classroom air.
- Replacing supply air filters had no effect but increasing the outdoor air supply rate did, so pollutants must originate indoors.
- The active pollutants could be bioeffluents or emissions from materials, or both.

# Conclusions on window opening

- Windows were opened to reduce classroom temperatures, not to improve IAQ.
- Natural ventilation did not ensure adequate ventilation, even with cross-ventilation.
- Split cooling, by eliminating the perceived need to open windows, decreased the air quality still further.
- Both slightly raised T and poor IAQ decreased children's performance.

# SOLUTIONS

(In order of first cost and sophistication)

- CO<sub>2</sub> sensor signals windows open/close.
- Computer operates windows optimally.
- CO<sub>2</sub> controlled by variable exhaust flow.
- Balanced 100% fresh air supply + exhaust.
- Pre-heat supply air and remove ozone.
- Recover heat from exhaust airflow.
- Remove pollutants from return air using a desiccant wheel purged with outdoor air.

# The Swegon Air Academy webinar series with Professor David Peter Wyon

Webinar 1:

Thermal and air quality effects on  
the performance of the schoolwork  
by children

Webinar 2:

Thermal and Indoor Air Quality  
Effects on the Performance of  
Office Work

[www.swegonairacademy.com](http://www.swegonairacademy.com)

How many hours?

Can we afford not to do something about this?

